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Arkhangelsk, Vologda, Leningrad, and Murmansk Regions, Republic of Karelia, and City of St. Petersburg

Konstantin Kobyakov and Jevgeni Jakovlev **(eds.)**

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The result of ecological gap analysis for nature conservation in northwest Russia to be utilized in international co-operation

Tapio Lindholm, Raimo Heikkilä, Anna Kuhmonen & Jevgeni Jakovlev

The importance of protected areas in preserving biodiversity on the landscape, community and species levels, as well as the selection of areas for conservation, have been under intensive discussion and research during recent decades. Nature conservation in Russia has rapidly gained international importance, with strong emphasis on the last remaining intact forests and mires of northwest Russia. This area is directly adjacent to the northern parts of the European Union, and is included within the Nordic co-operation framework as well as in the Barents Euro-Arctic Council and Arctic Council frameworks. The last remaining intact forests and mires of these high northern latitudes are among the largest intact ecosystems of international importance in the whole world. At present they are under increasing pressure from various forms of land use, exploitation and climate change. This sets a demand for the urgent development of a representative and efficient protected area network to preserve them.

Protected areas in northwest Russia differ in legal status, protection regimes, and functions. The pool of protected areas includes strict nature reserves (zapovedniks), national parks, nature parks, zakazniks (nature reserves or wildlife refuges) and nature monuments, as well as botanical gardens, arboretums, and nature spa resorts (healing landscapes). National parks, strict nature reserves, and a few zakazniks and botanical gardens have federal status and are managed by federal authorities. The rest (i.e. the majority) are managed by regional authorities, often directorates of protected areas of regional importance. Reflecting Russia's great size, protected areas there are typically large, but also small nature reserves are present, usually established locally by a municipality, to protect geological, zoological, botanical, or landscape features of limited area.

The parties to the Convention on Biological Diversity agreed on essential targets to reduce significantly loss of biodiversity by 2010. As one such target, each country was to implement a gap analysis to study the ecological gaps and representativeness of their protected area network to optimize its further development. The Gap analysis of the Russian Federation was implemented for the federal protected area network and its results were published in 2009 (Krever et al. 2009). This publication on Gap analysis of northwest Russia covers also protected areas of regional level, which contributes to their development.

The Finnish Environment Institute (SYKE) is a research institute which provides information, skills and services crucial to achieving sustainable development, both in Finland and globally. It has a long tradition of co-operative studies with Russian scientists aimed at the conservation of biological diversity, with results published in the international forum. In 2007, as a result of joint meetings between Finnish and Russian specialists in nature conservation, SYKE got the task of coordinating a project aimed at the analysis and assessment of the protected area network in northwest Russia. The project was important for creating a Geographical Information System (GIS) based approach to define areas with high conservation value and to analyze their coverage within the network of the existing and planned protected areas in Murmansk, Arkhangelsk, Vologda, and Leningrad Regions; the Republic of Karelia; and the City of St. Petersburg.

The results of the gap analysis were published in printed and electronic format in Russian in 2011, including an atlas of intact nature areas ranging from entire landscapes to key habitats of particular species. The analysis was made on the basis of information obtained from satellite images, topographic and thematic maps, and field inventory data. Among the major topics considered by the authors are protection efficiency and the representativeness of the existing protected area network; ecological gaps in the protected area network; protection proposals to improve representativeness of the protected area network in the identified high conservation value (HCV) areas, and other possible ways to protect biodiversity in northwest Russia.

Early on, a strong need for an English Edition of the project publication was highlighted. The selection of areas of high conservation value across such a large area as northwest Russia was obviously a challenging task even for a large research team. In the study the best available data from various sources have been used, including primarily satellite image data for remote sensing interpretation, and all available data from previous field surveys covering many parts of the study area. In addition, existing literature, maps, state forest-inventory data and records of plant and animal species have been used from all available areas. Expert visual interpretation of satellite images allows exact detection of extended high conservation value areas, like intact forest landscapes, intact forest tracts and mire massifs. Smaller high conservation value areas, like spring fens, sloping fens etc. are difficult to find using satellite images only, so their boundaries were delineated by combining the results of cartographic analysis, thematic maps and coordinates obtained with GPS-navigators during field surveys. In parts of the study area which were not covered with such detailed surveys, small high conservation value areas were not mapped. In the Republic of Karelia, many known records of red-listed plants, fungi and animals were not included in the maps, as their exact coordinates were not available. The English edition outlines the current situation and adapts Russian terminology and definitions to western usage.

The results offer important tools for local, regional, and federal planning of sustainable land use. In many regions recommendations to include areas of high conservational value in the protection plans have already been taken into account in the regional conservation plans, as planned protected areas. However, in many cases we are losing these areas due to logging (e.g. planned zakaznik Spokoyny in the Republic of Karelia), mining activities (e.g. planned Khibiny National Park in Murmansk Region), and construction (e.g. planned Ladoga Skerries National Park in the Republic of Karelia), because planned protected area status does not forbid these activities. The gap analysis has provided mapping of their boundaries, and has shown that satellite image data generally correlates well with biodiversity data from other sources. According to Russian legislation, in order to establish the necessary protected areas further studies are required, the results of which must be included in official documentation; thereafter a local hearing must be organized before the authorities can make a formal decision.

In this publication the status of all protected areas is dated for March 2011. Since the original Russian version of the atlas was finalized, new protected areas have been established, and new planned protected areas have been added to the conservation programs of the regions. In 2011, Lapland Forest zakaznik (171,672 ha) was established in Murmansk Region, between Russia's Lapland Strict Nature Reserve and Finland's Urho Kekkonen National Park. In 2013, Onega Pomorye (Onezhskoye Pomorye) National Park (201,668 ha) was established on the coast of the White Sea in Arkhangelsk Region. In addition, smaller protected areas have also been established since 2011.

The results of the Gap analysis in northwest Russia, including a GIS database, are currently being utilized in many fields of nature conservation work. For example, the Barents Protected Area Network (BPAN) project aims to promote and support the creation of a representative protected area network for the conservation of biodiversity and boreal-arctic nature in the Barents Euro-Arctic Region, including 13 regions of northwest Russia, northern Finland, Sweden and Norway. In this project, the entire protected area network is being evaluated and analyzed utilizing the results of the Gap analysis in northwest Russia together with similar information from the Nordic countries, the Republic of Komi and the Nenets Autonomous District (www.bpan.fi 2013). Also, a few high conservation value areas identified in this study were chosen as pilot sites to support the establishment of legally protected areas in these territories. The results of the BPAN project will be published in 2013.

We express our warmest thanks to Dr. *Oleg Kuznetsov* and Dr. *Alexei Kravchenko* of the Karelian Research Center of the Russian Academy of Sciences (Petrozavodsk) for their invaluable help in updating the text. Professor *Rauno Ruuhijärvi* and Forest Engineer *Jyri Mikkola* (Finland), members of the Finnish Gap project team, have made useful corrections in the English Edition. For the English Edition also additional photos were kindly provided by *Gennady Alexandrov, Andrey Humala, Anna Kuhmonen, Tapio Lindholm, Olli Manninen, Jyri Mikkola* and *Sergey Osipov.*

Background for the Gap analysis

Rauno Ruuhijärvi,
Emeritus Professor, former chair of the Finnish-Russian working group on nature conservation

Finnish-Russian intergovernmental co-operation began in 1985, when Finland and the Soviet Union signed an agreement for co-operation in environmental protection. This agreement was renewed with the Russian Federation in 1992, particularly highlighting Finland's co-operation with neighboring areas. The main themes of the approved program were protection of similar ecosystems and endangered species common to both countries, as well as related research. The Finnish-Russian working group on nature conservation was established for purposes of this co-operation. Activities have been financed through funds allocated for neighboring area and international co-operation by Finland's Ministry for Foreign Affairs and Ministry of the Environment. The joint projects are based at the Finnish Environment Institute, SYKE.

The first practical outcome of the joint activities was the establishment of the Friendship Park in 1990, on both sides of the border – in Kuhmo in Finland and Kostomuksha in Russia. The working group and project organization participated in the planning and development of the Vodlozero and Paanajärvi National Parks, as well as of a few protected areas of regional significance in the Murmansk, Arkhangelsk, and Leningrad Regions and the Republic of Karelia in the early 1990 s.

Since 1997, co-operation in nature conservation has been part of the Finnish-Russian Development Program on Sustainable Forest Management and Conservation of Biodiversity in Northwest Russia. It has carried out dozens of research, inventory, and publication projects in the administrative regions of northwest Russia, working with various organizations. The planning for new protected areas in the Republic of Karelia was carried out also with funding from the European Union's TACIS program at the turn of the millennium. Yet it has not led to the establishment of all the proposed protected areas. Long in the planning, Karelia's Kalevala National Park was finally established in 2007. Many planned protected areas, with co-operative preparations having lasted for 10-20 years, are currently still awaiting confirmation. Among these are Ladoga Skerries National Park, Ingermanlandsky Strict Nature Reserve and Khibiny National Park.

At the beginning of the millennium, the environmental administration of the Russian Federation was undergoing large-scale organizational changes. Amid these conditions, certain projects were continued and planning of the Gap analysis project for northwest Russia began. Its goal was to optimize the network of protected areas. No appropriate organization was found within the environmental administration of the Russian Federation. The Russian side of the Finnish-Russian working group on nature conservation lost its relevance because of the changes. Eventually our former partners, the regional administrations, academic institutions, and non-governmental organizations, became the actors of the Gap analysis project. Work in full began in 2007 in the Murmansk, Arkhangelsk, Vologda, and Leningrad Regions; the Republic of Karelia; and the City of St. Petersburg. Now we have the final results of the Gap project as a publication in our hands.

At the core of the Gap analysis project were consideration of the representativeness of the protected area network and the nature values in the existing protected areas. On this basis, the ecological gaps in protection were addressed and natural objects of high conservation value, such as old-growth forests and mire massifs and other valuable biotopes, as well as rare and endangered species, were sought, to improve the network of protected areas. The task was quite complex owing to the large spatial distances within northwest Russia and the lack of data on biodiversity, although some regions had already carried out work on conservation planning. In addition to traditional planning techniques such as fieldwork, collection of biodiversity data, and satellite imagery, the final stage of the project also employed new software using computation methods developed by Karelian scientists (see Chapter 3). Similar methods have entered use in conservation planning in many other countries, including Finland. Hard work on the processing of map data and interpretation of satellite images in the GIS was carried out by the non-profit partnership Transparent World, Moscow, headed by *Dmitry Aksenov*. For determining the boundaries of each new proposed protected area, further field research and socio-economic analysis are required. Hopefully that the participants' interregional networking will be visible in future projects, for which there are still many materials yet to be published.

The main partners implementing the Gap analysis project were:

- Non-commercial partnership Transparent World, Moscow, technical inter-regional co-ordination, GIS and cartographic material
- Directorate of specially protected natural areas of regional importance of Arkhangelsk Region
- World Wildlife Fund (WWF) Russia, Arkhangelsk branch
- Vologda State Pedagogical University;
- Karelian Regional Nature Conservancy NGO SPOK, Petrozavodsk
- Karelian Research Center of the Russian Academy of Sciences, Petrozavodsk
- Faculty of Biology and Soil Sciences, St. Petersburg State University
- Komarov Botanical Institute of the Russian Academy of Sciences, St. Petersburg
- Zoological Institute of the Russian Academy of Sciences, St. Petersburg
- Murmansk Regional public organization Kola Biodiversity Conservation Center, Murmansk
- Polar-Alpine Botanical Garden & Institute of the Kola Research Center of the Russian Academy of Sciences, Apatity.

Also specialists of many other Russian organizations took part in the project work in various phases and tasks. The Finnish Gap Working Group consists of specialists from environmental administration, research institutes and non-governmental organizations. Norwegian and Swedish colleagues supported the project work within the international contact forum (Habitat Contact Forum, HCF) and the Working Group of Environment of the Barents Euro-Arctic Council (BEAC WGE).

During the project work, a large number of seminars, working meetings, training events, and field trips have been conducted. These were attended by dozens of personnel from governmental authorities, research institutes, and public organizations. The Gap analysis project has also played an important educational role, which will undoubtedly manifest itself in the future.

The Finnish party responsible for the project wishes sincerely to thank all of the participants. The work has taught us all a lot. It has given us the purposes toward which we should continue, taught friendship and understanding, and provided an unforgettable opportunity to share experiences. We hope that our work will continue at the level of the Ministry of Natural Resources and Ecology of the Russian Federation and regional governments. The experts who have participated in the project are still available for the development and implementation of the proposals.

River valley in the Khibiny Mountains. Planned Khibiny National Park, Murmansk Region. Photo: Anna Kuhmonen.

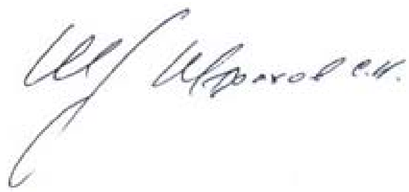
A generally accepted priority of Finnish-Russian co-operation is international co-operation in environmental protection. One of the objectives of the joint activities of the governments, scientific, educational and social organizations of the two countries is the study and protection of ecosystems and endangered species in adjacent territories.

The Gap Analysis project focused on the planning of protected areas in northwest Russia started at the beginning of the new millennium. The goal of the project is to develop scientific background and practical proposals for optimizing the network of protected areas in Murmansk, Arkhangelsk, Vologda and Leningrad Regions, the Republic of Karelia and the city of St. Petersburg.

The Gap Analysis project provides an overall picture of the real situation regarding protection of areas of high conservational value within the existing protected area network, and gives recommendations on how to improve it. Thus, local authorities at different levels have received background material for optimizing the protected area networks in their regions.

During the period of the implementation of the project, a significant amount of scientific data has been gained. This allows estimating the situation with nature protection in the existing protected areas in six regions of the Northwestern Federal District of the Russian Federation. The most important parts of these materials are included in this publication. Continuation of the studies aimed at preparing recommendations for optimizing the protected area networks and further publication of the results seems worthwhile and could be recommended for all regions of the Russian Federation included in the Gap Analysis project.

Shtrakhov, Sergey Nikolaevich, Minister of Natural Resources and Ecology of the Republic of Karelia.



The international Gap Analysis project covers the protected area network of six areas occupying the greater part of the territory of the Northwestern Federal District of the Russian Federation. The results of the project have revealed, among other things, many gaps in the regional protected area networks and "white spots" in our knowledge of the distribution of areas with high conservational value. These results, primarily GIS-materials and their scientific analysis, should be used in further studies on the inventory of biodiversity in the regions, the analysis of the legal basis of all protected areas in accordance with the current legislation, the regulatory framework for the protection of valuable natural habitats, the assessment of the representativeness of regional protected areas and its development.

Zavgorodny, Aleksander Mikhailovich, Head of the Department of Natural Resources and Environmental Protection of Vologda Region.

Ecology, environmental issues and sustainable development are among the priorities for the development of modern society. The project, Gap Analysis in Northwest Russia, appeared especially relevant for Arkhangelsk Region because of relatively poor knowledge on the distribution of valuable natural habitats inside and outside existing and planned protected areas. We needed to conduct a complex analysis of the effectiveness of the regional protected area network in order to bring it into line with modern requirements. This can help in providing sustainable development in the region and a supportive environment for its residents. Among the many results of the project, I want to note those proposals that have already been accepted and used during preparation work of the regional Concept Note on the protected area network in Arkhangelsk Region and Nenets Autonomous District. This document is a strategy for developing the network of protected areas at both federal and regional levels.

I think that the project has gained a lot of scientific results on the identification of natural patterns and relationships between different components of biogeocenoses. This is a solid foundation for the continuation of the work in the construction and development of the unified network of protected areas in the Barents Region, and for science-based establishment of new protected areas.

Shabalin, Ivan Pavlovich, Head of the Agency of Natural Resources and Ecology of the Arkhangelsk Region.

The project Gap Analysis in Northwest Russia was extremely relevant to Murmansk Region.

It has been conducted during the same time when the government has been preparing the Concept of Development of a network of specially protected natural territories of Murmansk Region. The results of the Gap Analysis were properly used in defining the priorities for the organization of new national and nature parks, zakazniks and nature monuments.

It is very important that the results of the project show that the goals of nature protection, saving endangered species, and preservation of intact natural ecosystems do not contradict the goals of economic development of the region. They can be run together, complementing each other.

Krapivin, Oleg Vladimirovich, Chairman of the Committee of Industrial Development, Ecology and Nature Use of Murmansk Region.

CONTENTS

Introduction

A generally accepted priority of Finnish-Russian relations is international co-operation in environmental protection. This is no accident: natural areas are not restricted by administrative boundaries so the environment in one country has a direct impact on neighboring countries. Therefore many environmental actions should be implemented at the international level. More than 50 mutual projects were carried out during the period of 1997-2011 in the areas along the Finnish-Russian state border and adjacent regions, within the framework of the Finnish-Russian Development Programme on Sustainable Forest Management and Conservation of Biodiversity in Northwest Russia. The main objectives of these projects were identification of valuable natural complexes and areas, research on biodiversity, publication of regional Red Data Books, creation of new protected areas and improving the management of existing protected areas.

The Green Belt of Fennoscandia is one of the main initiatives towards increased level of nature protection in northern Europe. The idea of creating the Green Belt of Fennoscandia was first raised in the early 1990s. This can be considered as a start for long-term joint-work to create new protected areas in the both sides of the Finnish-Russian border. The border area 1,250 kilometers long, is very important territory for conserving the biological diversity of boreal forests and other biotopes that have been preserved in a natural state. The endangered species of their flora and fauna need safeguarding. The Green Belt of Fennoscandia includes existing and planned protected areas of different status in the area stretching from the Gulf of Finland in the south to the Barents Sea in the north. This zone also provides unique possibilities for research, environmental management and co-operation in the fields of culture and tourism. Protected areas, with their research and monitoring centers, provide an excellent pilot zone of great length from north to south for studying the effects of climate change on biological diversity.

Co-operation on the Green Belt of Fennoscandia is based on the Finnish-Norwegian-Russian Memorandum of Understanding (MoU), signed by the Ministers of the Environment from each country, in 2010. This Memorandum facilitates ecologically, economically, socially and culturally sustainable transboundary co-operation throughout the Finnish-Norwegian, Finnish-Russian and Norwegian-Russian parts of the Green Belt of Fennoscandia. It expresses the political will of the participating countries to cooperate over halting loss of biodiversity and to strive for the goals set by the international Convention on Biological Diversity (Rio de Janeiro, 1992). The main objectives of the development of the Green Belt of Fennoscandia include further optimization of the network of protected areas, and further development of co-operation in sustainable use of nature areas with high conservation value. The analysis of the representativeness of the existing network of protected areas and the identification of gaps in it are the most urgent tasks.

The Russian Federation ratified the Convention on Biological Diversity in 1995. In 1997, Russia published a national report on the conservation of biological diversity in Russia, which outlined what Russia is doing to implement the goals of this convention. Optimal development of the network of protected areas can provide protection of significant areas which have high conservational value, together with their viable populations of plants and animals. Therefore, in 2004, all signatory countries to the Convention on Biological Diversity accepted a special program on the development of protected areas. The aim of the program is to promote the establishment and operation of comprehensive, effective and ecologically representative national and regional systems of protected areas. This means that all countries should conduct a kind of gap analysis in order to evaluate the biological representativeness of their national and regional networks of protected areas, to identify gaps in the coverage of the areas of high conservational value by the existing protected areas, and then to maximize the potential of protected areas, including improvement of management processes. National plans to provide urgent interim protective measures for valuable natural areas under high threat should be worked out, where necessary.

To comply with international obligations, the Ministry of Natural Resources and Ecology of the Russian Federation asked the Russian branch of the World Wildlife Fund (WWF) to evaluate the representativeness of the existing system of protected areas of federal level (primarily strict nature reserves and national parks) and to determine its developmental priorities. WWF has implemented this project in 2006-2009, and the results have been published in printed and electronic formats (Krever et al. 2009).

Implementation of the project "Gap analysis in northwest Russia" started in 2007, but preparations for it began much earlier. The Gap project working group invited participation from the organizations and experts who possess the most complete information on the distribution, characteristics and threats to the areas of high conservational value in the studied territory. The aim of the project is to analyze the biological representativeness of the network of existing and planned protected areas and identify possible gaps, in six regions of the Northwestern Federal District of the Russian Federation. This area is smaller than in the pan-Russian WWF project, but the Gap analysis of northwest Russia study is more detailed. The analysis includes protected areas of both federal and regional levels.

The study area includes the following six administrative units of northwest Russia: Murmansk, Arkhangelsk (excluding the Nenets Autonomous District and the Arctic islands), Vologda and Leningrad Regions, Republic of Karelia, and City of St. Petersburg. These regions differ from each other considerably in such factors as size, natural conditions, level of knowledge of natural areas, flora and fauna, and regional legislation, but they also have much in common. For the local authorities making decisions on land use, the results of the Gap analysis project provide background material to help make the network of protected areas at federal, regional and local levels more effective.

In addition to the Convention on Biological Diversity and the Green Belt of Fennoscandia, the result of the Gap analysis will be useful for the implementation of other international conventions and agreements: the Ramsar Convention (Convention on Wetlands of International Importance especially as Waterfowl Habitat, Ramsar 1971), the Helsinki Convention (Convention on the Protection of the Marine Environment of the Baltic Sea, Helsinki 1992), the UN Framework Convention on Climate Change (New York 1992) and the Kyoto Protocol (1997).

Publication of the results of the project Gap analysis in northwest Russia is also designed for ecologists, nature conservationists, students of natural science disciplines and the wide range of readers who are interested in natural heritage and its conservation. The report is issued in printed and electronic formats. The availability of the online version ensures transparency and accessibility of the project results. Besides the general inter-regional report which is presented in this publication, the regions are releasing some more detailed and special editions. The project has been completed, but work on identifying gaps in nature conservation in northwest Russia, as well as work on closin these gaps, continues at the regional, national and international levels.

Intact dry pine forest. Complex landscape zakaznik Arctic Circle, Republic of Karelia. Photo: Gennady Aleksandrov.

1. GENERAL DESCRIPTION OF THE NATURAL ENVIRONMENT AND DEVELOPMENT OF NORTHWEST RUSSIA

Nadezhda Maksutova, Aleksander Kirillov, Konstantin Kobyakov, Dmitry Koltsov, Anton Korosov & Georgy Noskov.
Editor: Nadezhda Maksutova

1.1. Characteristics of nature of northwest Russia

1.1.1. Geographical position

The area considered within the framework of the Russian-Finnish project "Gap analysis of the Protected Areas Network in northwest Russia" is located on the northwest margin of the European part of Russia and geographically covers the north of the East European Plain. According to the administrative division of the Russian Federation, this area belongs to the Northwestern Federal District and includes six administrative units (hereafter "region") of the Russian Federation, viz.: Arkhangelsk Region (excluding Nenets Autonomous District and the archipelagoes of Franz Josef Land and Novaya Zemlya), Vologda Region, Leningrad Region, Murmansk Region, the Republic of Karelia and the City of St. Petersburg. The total area (including inland waters) is 869,200 km^2, which is 5.06% of the whole territory of the Russian Federation (Fig. 1.1 and Table1.1). This area will be called below: "northwest Russia."

Marine areas are under federal, not regional governance, so formally they cannot be considered as part of the area of the Russian Federation studied within the Gap analysis project. However, some of the valuable natural areas included in the study are located on the shores and islands of the Barents, White, and Baltic Seas. Therefore, in this publication, we include in the analysis also those portions of the marine waters adjacent to these valuable natural areas within the territorial waters of the Russian Federation. Since marine areas do not belong officially to particular regions, we include in the tables and figures for the valuable natural areas only the values of their total areas without calculation of their share of the area of the various regions considered in this study.

Arkhangelsk Region is considered in this publication as the mainland, excluding the Nenets Autonomous District (NAD) and two archipelagoes in the Arctic Ocean: Franz Josef Land and Novaya Zemlya. Arkhangelsk Region is washed on the northwest by the White Sea. In the west it adjoins on the Republic of Karelia, in the south the Vologda and Kirov Regions, in the east on the Republic of Komi, and in the north NAD. Arkhangelsk Region covers a total of 314,000 km^2, or 1.8% of the whole territory of the Russian Federation (Pomor Encyclopedy 2007). It covers 36.1% of the territory studied under the "Gap-analysis" project.

Vologda Region borders to the south with four regions of the Russian Federation, Tver, Yaroslavl, Kostroma and Novgorod. In the west it borders on Leningrad Region, in the north on the Republic of Karelia and Arkhangelsk Region, in the east on Kirov Region. The total area of Vologda Region is 144,500 km^2 i.e. 0.85% of the whole territory of the Russian Federation and 16.6% of the area covered under the Gap analysis project. The sixth parallel (60° N) divides the region into two almost equal parts (Atlas of topographic maps of Vologda Region, 2007).

The **Republic of Karelia** is washed on the north by the White Sea. The western border of the Republic runs along the state border with Finland, while in the south it borders on the Leningrad and Vologda Regions, in the north on Murmansk Region and in the east on Arkhangelsk Region. The total area of the Republic is 180,500 km^2, or 1.06 % of the whole territory of the Russian Federation and 20.8% of the area covered under the Gap analysis project. The Republic extends 660 km from north to south, 424 km from east to west.

Leningrad Region borders in the west on the Baltic Sea, the City of St.Petersburg, and also with the states of Finland and Estonia. In the south it has borders with the Novgorod and Pskov Regions, in the east with Vologda Region, and in the north with the Republic of Karelia. The total area of Leningrad Region is 83,900 km^2 , which is 0.49% of the territory of the Russian Federation, and 9.7% of that covered under the Gap analysis project).

Murmansk Region has borders in the west with Norway and Finland, and in the south with the Republic of Karelia. Its coasts are washed by the White and Barents Seas. Almost the entire territory of the region is located north of the Arctic Circle. Besides the mainland part, Murmansk Region includes islands of the coastal area of the Kola Peninsula (including the archipelagoes of the Ainovy Islands, Seven Islands, and several single islands, e.g. Kildin, Morzhovets, etc.). The total area is 144,900 km^2 or 0.85% of the total area of

Fig.1.1. Administrative division of the territory studied in the framework of the project "Gap analysis of the Protected Areas Network in Northwest Russia"
Key to map numbers: 1 - Norway, 2 - Sweden 3 - Gulf of Finland, 4 - Pskov Region, 5 – Novgorod Region, 6 - Tver Region 7 - Yaroslavl Region, 8 - Kostroma Region, 9 – Kirov Region, 10 - Republic of Komi, 11 - Nenets Autonomous District.

Table 1.1. Administrative Regions of the Northwestern Federal District of the Russian Federation studied within the framework of the project "Gap analysis of the Protected Areas Network in Northwest Russia"
(after: "Territory and administrative division of the Russian Federation on 1 January 2010. Data by federal agency state registration, Cadaster, and Cartography" (Rosreestr) obtained from the Website of Federal State Statistic Service of the Russian Federation (Rosstat) (http://www.gks.ru/wps/wcm/connect/rosstat/rosstatsite.eng/).

Region	Area 1000 km2	% of total area of Russian Federation	% of total area of Northwestern Federal District	% of territory studied in Gap analysis project
Arkhangelsk Region*	314.0	1.80	18.7	36.1
Vologda Region	144.5	0.85	8.6	16.6
Republic of Karelia	180.5	1.06	10.7	20.8
Leningrad Region	83.9	0.49	4.9	9.7
Murmansk Region	144.9	0.85	8.6	16.7
City of St. Petersburg	1.4	0.01	0.1	0.2
TOTAL	869.2	5.06	51.6	100

* excluding the Nenets Autonomous District and the Arctic archipelagoes

the Russian Federation and 16.7% of the project area. Murmansk Region extends over 550 km from west to east and about 400 km from north to south (Atlas of topographic maps of Murmansk Region 1971, 2007).

St. Petersburg is a major metropolis of the Russian Federation, the northernmost city in Russia with a population of over one million. St. Petersburg lies on the Gulf of Finland at the mouth of the River Neva. On its mainland side the city is surrounded by Leningrad Region. The total area of the City of St. Petersburg is 1,439 km^2 or 0.16% of the area covered under the Gap analysis project. In Chapter 1 the area of St. Petersburg is not considered.

1.1.2. Geological characteristics and relief

Northwest Russia lies in the northwest part of the East European Platform on two adjacent tectonic structures, the Russian Plate and the Fennoscandian or Baltic Shield. It consists of a gently undulating plain which reflects the features of the geological, tectonic structure and the composition of rocks. The modern relief is the result of long-term geological processes which have produced a mosaic of varied habitats.

The ancient pre-Cambrian Baltic Shield is an old structural geological unit that has kept its main non-sedimentary character for the last billion years or more. Exposed bedrock areas of the Shield occur widely in Murmansk Region, e.g. the Kola Peninsula, several places in the Republic of Karelia and in the Karelian Isthmus of Leningrad Region. Early Archean crystalline rocks are distributed throughout the whole Lapland-Kola-Karelian geological area, which has been formed through ancient orogenic processes and other tectonic movements.

In the zones of deep tectonic faults, the largest structures are the crustal blocks, viz.: Murmansk, Kola, White Sea, Karelian, Tersky, Keyvsky and Inari blocks. They are largely formed of Late Archean crystalline rocks. Within the Kola Peninsula, traces of the Proterozoic and Paleozoic magmatic processes are discernible in all the structures of the Baltic Shield. They are represented by numerous extrusions forming mountain (fell-) massifs, e.g. Monchepluton, Pansky, Main Ridge, Kandalaksha, Kolvitsa, Litsko-Uragubsky, Strelna etc., and single mountains (fells) like Mts. Generalskaya, Pyrshin, Fedorova, etc. Two mountain(fells) massifs, Khibiny Massif or Khibiny Tundras and Lovozero Massif or Lovozero Tundras located in the center of the Kola Peninsula, are formed by large intrusive plutons of the central type.

In Leningrad Region the occurrence of exposed Cambrian strata is typical for the Baltic-Ladoga lowland (also called "the Pre-Klint lowland" because it is bounded on the southeast by the Baltic-Ladoga Klint or scarp). The adjacent areas southward are covered by younger Devonian strata, which form the Main Devonian field and appear as outcrops along river valleys. In Vologda Region, Devonian outcrops like Andoma Hill occur in the northwestern part, on the southeastern coast of Lake Onega. The dominant sediments here are from the Permian, whereas in the southern part of Vologda Region Triassic sediments are more common.

The tectonic basis of the relief of the pre-Quaternary surface was formed by the early Pleistocene.

Later changes have resulted in several morphogenetic relief types, dominated by glacial ice and water reliefs. In the pre-Quaternary, deep extensive valleys were typical. The position of the ancient network of river valleys often does not coincide with their present situation.

The faulted characters of the morphostructures are clearly seen in the orography. The straight faults and orientation of most of the major river valleys, chiefly rectilinear, indicate the links between the modern relief and a system of ancient faults and tectonic fractures. The general slope of the landforms is apparent from the orientation of the large rivers: the Severnaya Dvina (hereafter the Northern Dvina River), Vuoksi, Onega, Mosha, Vaga, Suda, Pinega and Mezen all have northwest oriented valleys. The major tributaries of the Onega, Northern Dvina, Pinega, Mezen, Sukhona and Vychegda (the latter in its lower part) all have northeast oriented valleys. This mutually perpendicular orientation of the rivers flowing through the major lowlands (i.e. the Vozhe-Lachin, Sukhona, Mologa-Sheksna, Vodla, Mosha, Vaga and Severodvinsk lowlands), enhances the insular nature of the interfluvial elevated plains.

Ground-denudation plains and low mountains make up the predominant landforms in the relief of the Baltic Shield. There are relatively low hills and fells with a height of 300-600 m asl. e.g. Maanselkä, Suomenselkä, the West-Karelian elevation, etc. (see Fig. 1.2). In Murmansk Region there are even more massive and higher hills and plateus, all the way up to 1000 m asl. (Khibiny Massif 1206 m asl). The relief of the Baltic Shield is the result of long-term continental denudation and exposure of crustal structural forms, composed of relatively strong rocks. Tectonic movements during modern times, especially faults bounding mountain massifs, lowlands, river valleys and numerous lake basins, are largely responsible for the diversity of the present-day relief. During the Anthropogenic Era, this area was at the center of the glaciation processes in the Baltic Shield, so fresh glacial relief forms are common.

The relief of the Russian Plate is a combination, on the one hand, of erosional and denudation-tectonic landforms and, on the other, of accumulative plains. This relief, with gentle hills in combination with generally flat moraine areas, is most common in watershed areas. Outcrops of bedrock are found in the valleys of major rivers and their tributaries. The main distinctive features of the Russian Plate vs. the Baltic Shield are general softness of the relief forms compared with these rugged lowland watersheds.

The formation of the modern relief of northwest Russia has been profoundly affected by the activity of glaciers, surface and groundwater, wind, freezing and thawing processes. The last glaciation had the greatest effect on shaping present-day topography. The formation of hilly moraine ridges, which are the most widespread type of glacial relief, is usually associated with the process of melting of sedentary ice. The most significant areas of hilly terrain-ridge relief are situated in the central part of Murmansk Region, south and north of the Khibiny and Lovozero Tundras. Similar formations are also distributed along the periphery of Murmansk Region, in the northeast, southeast and south. In the western part of the region, hilly moraine ridges occur mainly along the broad river valleys and around the major lake basins.

Irregularly shaped moraine hills and radial glacifluvial ridges (i.e. kames and eskers) are widely distributed throughout the study area. This glacial relief is best expressed by glacial topography in the west-northwest of the territory, where the primary forms of the end morainic formations of the last glaciation, viz.: the Baltic Sea, West-Karelian, Veps, Belozersk, and Konosha-Nyandoma elevations, and the Ondomozersk's Caves are preserved. From its characteristic abundance of lakes this area is called Lakeland.

More ancient topography dating from the Moscow and Dnepr glaciations can be seen in the southeast of the study area, for instance in Vologda Region, where slightly undulating moraine plains with traces of later erosion are widespread.

Arkhangelsk, Vologda and Leningrad Regions together with the Republic of Karelia occupy a part of the Russian Plain watershed between the White, Baltic and Caspian Seas. The only junction of the basins of these three seas in the Russian Plain is situated in Vologda Region (Kulikov 2000, Vorobyev & Kulikov 2000).

In the **Arkhangelsk Region**, coastal lowlands with heights up to 70 m asl occupy vast areas along the shores of the White and Barents Seas. They are separated by the White Sea-Kuloi plateau and by the outlier hills of the Onega Peninsula into five depressions, viz.: the Pribelomorskaya, the Mezen, the Unsko-Ukhta, the Lower Onega River and the Nizhneseverodvinskaya lowlands. Slightly uplifted plains, with maximum altitudes reaching 100-250 meters asl, are situated south of the coastal lowlands. Among them, the North Onega, the Andoma-Kenozero, the Onega-Dvina, the Dvina-Mezen elevations, together

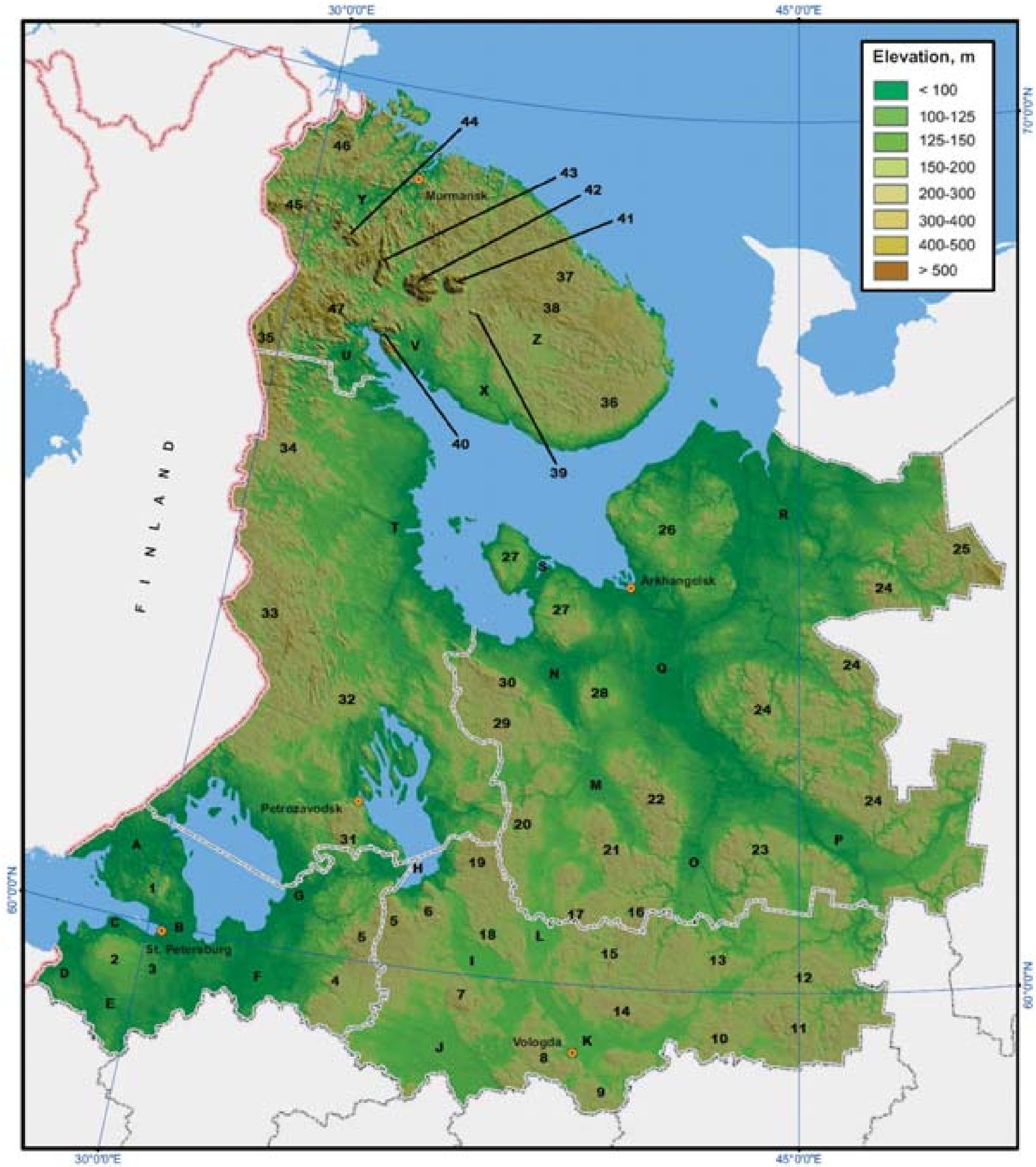


Fig.1.2. Relief map.

A) Vyborg-Vuoksi Lowlands, **B)** Neva Lowland, **C)** Baltic-Ladoga/Maritime/Pre-Klint Lowland, **D)** Pljussa Lowland, **E)** Luga Lowland, **F)** Volkhov-Tikhvin Lowlands, **G)** Swir Lowlands, **H)** Onega Lowland, **I)** Belozersk Plain, **J)** Mologa-Sheksna Lowlands, **K)** Sukhona Lowland, **L)** Charozero Lowland, **M)** Onega-Mosha Lowland , **N)** Lower Onega River Lowland, **O)** Vaga River Lowland, **P)** Upper Dvina Lowland, **Q)** Lower Dvina Lowlands, **R)** Mezen Lowlands, **S)** Una Lowland, **T)** The White Sea Lowlands, **U)** Kandalaksha Lowland, **V)** Umba Lowland, **X)** Varzuga Lowland, **Y)** Tuloma River Valley, **Z)** Ponoy Depression.

1) Lembolovo Elevation, **2)** Izhora Elevation, **3)** Putilov Plateau, **4)** Tikhvin Ridge, **5)** Vepsky Hills, **6)** Megorsk Ridge **7)** Andoga Ridge, **8)** Vologda Hills, **9)** Gryazovets Hills, **10)** Galich Elevation, **11)** Severnye Uvaly, **12)** Kichmen Plain, **13)** Sukhona-Tarnog Plain, **14)** Kharovsk Ridge, **15)** Kuloi Plain, **16)** Upper Vaga Elevation, **17)** Konosha Elevation, **18)** Kirillov Ridge, **19)** Andoma Elevation, **20)** Andoma-Ken-ozero Plain, **21)** Nyandoma Elevation, **22)** Onega-Dvina Elevation, **23)** Ustyansky Elevation, **24)** Dvina-Mezen Elevation, **25)** Timan Ridge, **26)** White Sea-Kuloi Plateau, **27)** Onega Ridges, **28)** North Onega Elevation, **29)** East Karelian Plain, **30)** Vetreny Poyas, **31)** Olonets Elevation, **32)** Central Karelian Belt, **33)** West Karelian Upland, **34)** North Karelian Upland, **35)** Maanselkä, **36)** Terskye Keivy Ridge, **37)** North Kola Upland, **38)** Keivy Ridge, **39)** Pansky Tundra, **40)** Kandalaksha and Kolvitsa Tundras, **41)** Lovozero Tundra, **42)** Khibiny Tundra, **43)** Chunatundra, Monchetundra & the Main Ridge, **44)** Salnye Tundras, **45)** Saariselkä, **46)** Pechenga Tundras, **47)** Kaita Tundras.

with the Vetreny Poys (Windy Belt) and the northern part of the Northern Ridges, are the biggest.

In **Vologda Region** hilly elevations are combined with flat uplifted morainic plains. The former are associated with the northeastern spurs of the Valdai Hills of the Russian Plain, including the Veps and Andoma elevations and the northern part of the Galich elevation, as well as the Megorsk ridge and the southwestern part of the Northern Ridges. The morainic ridges and plains are represented by the Belozersk, Kirillov and Andoga ridges, the Vologda and the Gryazovets hills, the Kuloi-, Sukhona-Tarnog-, and Kichmen moraine plains.

In the **Republic of Karelia** a ridge-hilly denudation-tectonic landform (called "selkä") is represented by abrasion and accumulation glacial and glacifluvial deposits which may take various forms, such as moraine hills, kames and eskers. The mosaic of these varied formations in combination with ravines and synclines occupied by lakes and rivers, produces a landscape of great beauty.

The northwestern part of **Leningrad Region**, the Karelian Isthmus, has, from north to south, four distinctive parts. In the north, near the Finnish border there is an area of northwest oriented river valleys sided by rocky ledges typical of the Baltic Shield area, and rolling hills between the valleys. The southeastern edge of the Baltic shield runs in the middle of the Vyborg-Vuoksi lowlands, on an area where there once was the ancient Heinäjoki Strait connecting the Baltic Sea and Ladoga Lake. The central part of the Isthmus is occupied by massive esker-formation called Väärämäenselkä and the Lembolovo elevation (up to 203 m asl.), and the southern parts belong to Neva lowland.

The southwestern part of Leningrad Region is occupied by the Luga, Pljussa and Baltic-Ladoga (Maritime) lowlands surrounding the Izhora elevation, also called the Ordovician Plateau and composed of Ordovician carbonate rocks. The adjacent territory eastwards to Mga River is occupied by the Putilov Plateau, whose surface outcrops date from the Carbon age. The northern edge of the Ordovician and Putilov plateaus is formed by the Baltic Klint, an approximately 1200 km long limestone scarp reaching from Gotland, Sweden, through Estonia to the southern side of Ladoga Lake in Russia. The Baltic-Ladoga lowland located just below the Klint is also known as the Pre-Klint lowland.

The central parts of Leningrad Region are dominated by the Volkhov-Tikhvin and Swir Lowlands.

Outcrops of late-proterozoic sandstone on the Sredny Peninsula, Murmansk Region. Photo: Gennady Alexandrov.

The eastern parts of the region are occupied by the northern spurs of the extended Valdai-Onega elevation, consisting (in the Leningrad Region territory) of the Lodeinoye Pole elevation, the Tikhvin ridge and the western part of the Vepsky hills, where the western slopes are bounded by the Valdai-Onega (Carboniferous) scarp weakly expressed in the relief.

The main features of the relief of **Murmansk Region** are the Khibiny and the Lovozero massifs, or the Khibiny and Lovozero Tundras, which represent the largest mountain massifs in the study area. They are divided by deep valleys, radiating from or concentric about their centers, with glacial morphosculptures like deep bowl-shaped cavities, so-called circs or kars, marking the birthplaces of former glaciers. This gives them a distinctive alpine image.

Large areas composed of limestone and carbonate rocks contribute to the development of karst, which is present in an open or latent form in the Arkhangelsk, Vologda and Leningrad Regions. Karst is present in both ancient and young forms: karst sinkholes, lakes, disappearing rivers, depressions, craters, ditches, ravines, synclines and dry valleys. In addition, rare and unique forms of surface karst include "potyazhiny" (i.e. grooves), karst-glacial valleys, so-called "shelopnyak" fields (i.e. sites of a polygonal shape covering some square kilometers of bare and poorly coated karst, including horizontal [tunnels, caves] and vertical [channels, wells, etc.] forms), buttes, towers, depressions, and outliers. Underground karst topography covers the collection of cavities created below the surface in the form of simple and complex cavities.

Permian sedimentary outcrop, Opoki zakaznik, Vologda Region. Photo: Elena Belozorova.

In Leningrad Region, karst formations are found chiefly within the Izhora and Putilov elevations. A lot of karst craters, swallow holes (ponors) and small sinkholes are found there. On the other hand, there is neither an extensive ground drainage system, nor lakes. Thus, the main discharge of groundwaters happens via the walls of limestone cliffs (Klint) and the springs below them.

In the Arkhangelsk Region, karst formations dominate the White Sea-Kuloi plateau, both on the surface and below it. A total of 404 caves are registered there, twenty three of them with a length of 1 km or more. The origin of 90% of them is connected with the gypsum karst (Pomor Encyclopedy 2007).

In Vologda Region, karst is found in the form of sinkholes, swallow holes and periodically disappearing rivers and lakes within the Veps and Andoma Hills, the Kuloi plateau and Kichmen-Sukhona plain.

Dune formations, whose development is quite active at present, are widely distributed on sandy accumulation terraces, both marine and lacustrine. The erosion process is especially strong on sites where the vegetation stabilizing the sand surface is in decline due to the impact of man and domestic animals. The greatest young aeolian sand-clay formations can be found on the shores of the Baltic and White Seas and large lakes: Ladoga, Onega, and Beloye Lake.

Permafrost and thermokarst morphosculptures occur only in Arkhangelsk Region.

Thus, within the study area, there is a wide range of diverse and unique geological and geomorphological sites deserving protection: stratigraphic, lithological, paleontological, landscape, tectonic, and hydrological. These sites include hills and ridges of varied origin, river valleys, disappearing karst rivers and lakes, man-made tunnels, catacombs, mines, mineral deposits, sources of fresh and mineral waters, natural outcrops, etc.

1.1.3. Climate and microclimate regimes, weather types

The climate of the region is defined by its geographic location in northern Europe and the proximity of the Arctic Ocean and the Atlantic Ocean. The amount of incoming solar radiation increases throughout the year from north to south in accordance with the changing of the sun's elevation. However, in the period from May to June the combination of the long days and sun elevation provides fairly high values of total solar radiation in the north. Winter is characterised by long nights and short days with twilight falling shortly after midday. Cloud, frequent fog and high relative humidity significantly reduce the amount of direct solar radiation. The warm North Cape drift in the Barents Sea along the north coast of the Kola Peninsula has a strong influence on the climate.

According to the classification of Alisov & Poltaraus (1974), the climatic system of the region includes zones with sub-arctic and temperate climate (Figure 1.3). Air masses of Atlantic and Arctic origin predominate all year round. Thus, the climate of the region is characterized by long but relatively mild winters, a late spring with frequent cold spells, a short cool summer, high relative air humidity, a considerable amount of precipitation and unstable weather conditions throughout the year. This type of climate is a consequence of the characteristics of the circulation system, the amount of incoming solar radiation (itself dependent on the geographical latitude of the territory), proximity to the Baltic, White and Barents seas, intense cyclonic activity in all seasons, and of the variety of highly diverse local natural features such as relief, the abundance of lakes and wetlands, large forested areas, etc.

Fig. 1.3. Climatic zones and regions (after Alisov & Poltaraus 1974). Subarctic-Boreal zone: 5) Atlantic (wet, moderately cold). Temperate zones: 8) Atlantic-Boreal (very moist, moderately warm), 9) Boreo-nemoral European (moderately moist, moderately warm)

In winter, when the inflow of solar radiation is small or totally absent (e.g. north of the Arctic Circle), the main climate-forming factor is the air circulation. The influence of warm Atlantic air results in significant variations in winter average monthly temperatures from -6 ° C in the southwest of Leningrad Region to -16 ° C in the northeast of Arkhangelsk Region (Fig. 1.4a).

In summer the contrasts are not so drastic. Mean daily air temperatures vary between 8 ° C on the northern coasts to 16 ° C in the south of the Vologda Region (Fig. 1.4b). As a result of substantial heterogeneity of the relief and a variety of the air circulation, local meso- and microclimate regimes, especially pronounced during the warm period, are typical throughout the region. The growing season lasts up to 60 days in the northeast of the mainland part of the study area (Pomor Encyclopedy 2007) and up to 180 days in the south (Nature of Vologda Region 2007).

Precipitation is mainly in the form of snow during the cold period in the northern latitudes, but the distribution of total precipitation is uneven due to the great size of the territory.

Annual precipitation (400-500 mm/year) is lowest in the river valleys and plains. In areas with complex relief rainfall is unevenly distributed. In elevated areas mean annual precipitation is 600-800 mm on windward slopes, but exceeds 1000 mm on the tops of major mountain massifs like the Khibiny Massif and the Lovozero, Monche and Chuna Tundras.

Winter monthly precipitation varies only slightly throughout the whole study area, from 30-40 mm. An exception is the southwest part of Leningrad Region where the monthly total can reach 50 mm (Figure 1.5a). In the north of the study area permanent snow cover forms during October and persists, on average, 180 days. On the tops of the Khibiny Massif and Chunatundra snow may persist for 220 days. Snow depth averages 70 cm throughout the area with the exception of the Murmansk coast of the Barents Sea, where snow cover is kept down to about 40 cm by the wind. (Yakovlev 1961, Agroclimatic resources ... 1971, Regional climate changes ... 2003, Kola Encyclopedy 2009).

However, in summer monthly total precipitation is characterized by large variations throughout the territory. In the north, on the coasts of the White and Barents Seas, monthly precipitation totals do not exceed 30-40 mm. In the south of Vologda and Leningrad Regions these values can reach 75 mm (Figure 1.5b). In the warm season, incoming air masses have higher moisture content than in winter, increasing both the volume and intensity of precipitation. Precipitation in the warmest summer months (July-August) is approximately double that in the coldest winter months (February-March).

Winter: spruce forest close to timberline. Murmansk Region. Photo: Georgy Kasyanov.

In the Kola Peninsula precipitation everywhere exceeds evaporation by about 1.4-1.6 times. Thus, as a result of substantial cloudiness, low summer temperatures and low evaporation, Kola Peninsula lies in a cold humid climate zone. The cloud cover is densest (magnitudes up to 7) on the northwest coast of the Peninsula, washed by the Barents Sea.

Snowstorm in the Khibiny. Photo: Georgy Kasyanov.

Annual variations of cloud cover are generally characterized by minimum cloudiness in summer with peak cloudiness in late autumn and winter. In the presence of cloud cover, total solar radiation is determined not only by the number and shape of the clouds, but also by the state of the solar disk. The emergence of an open cloud sun leads to an increase in radiation due to the increase of the scattered radiation. Occurrence of fogs is most often caused by variations in air temperature and air humidity. The mean annual number of foggy days in the Republic of Karelia and Murmansk Region varies from 80 to 100. Fogs are least common between May and July (1-4 days per month) and most common in the months of August and October (between 5-9 days).

The wind regime in the study area (velocity, prevailing wind direction, etc.) is determined by the seasonal dynamics of pressure centers and by local relief, which can distort the general wind pattern. Winter and spring are characterized by maximum wind velocity. Very large horizontal pressure gradients occur near the coasts of the northern seas, where the average monthly wind velocity ranges from 3 m/s on the continent to 9 m/s or more over open waters. Snowstorms occur in the area from September to June. The annual number of days with snowstorms varies from 25 to 55 across the study area, increasing in frequency towards midwinter and reaching a maximum in January. This is due to the coincidence of intense wind activity with a peak in the rate of snow precipitation and maximum dryness of snow. There may be up to 10-13 (exceptionally 20) days per month with snowstorms at this time of the year. By April their frequency has decreased substantially to 1-3 days per month. In some years snowstorms may occasionally occur in May and even in June.

Average monthly wind velocities range from 4-5 m/s on the open shores of large lakes to 7-8 m/s on the islands of Lake Ladoga and Lake Onega. During the summer season wind velocities decrease to an average of 2.5-3.5 m/s on land and 4-5 m/s on the islands. Daily variations in wind velocity are most clearly observed during the warmer part of the year, particularly from May to August.

The most dangerous atmospheric phenomena are wind associated. However, during the years 1936-2006 the average annual wind speed decreased

Summer in the far north is short and mild. *Petasites radiatus* prefer moist environments such as riverbanks, marshes and ditches. Photo: Georgy Kasyanov.

Autumn in the Khibiny. Photo: Gennady Alexandrov.

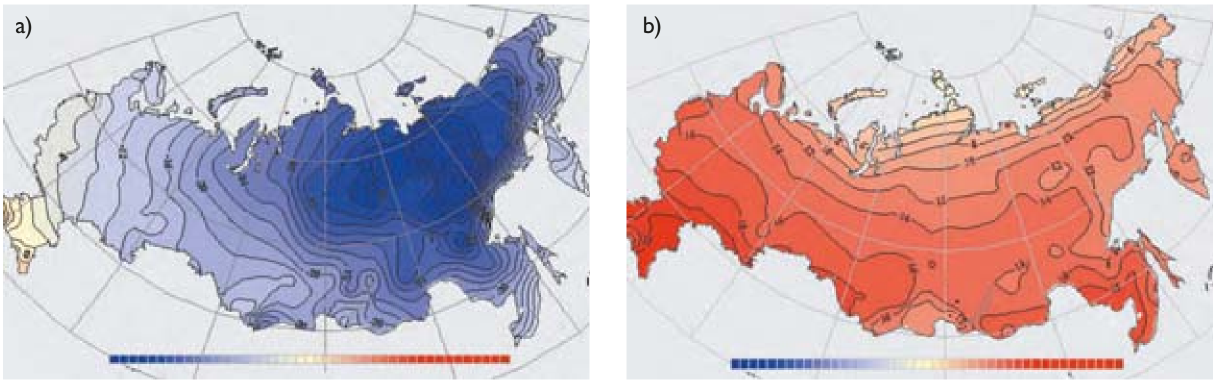


Fig. 1.4. Average surface air temperature (° C) in winter (a) and in summer (b) for the period 1961-1990.
(After: Report on climate changes …2008).

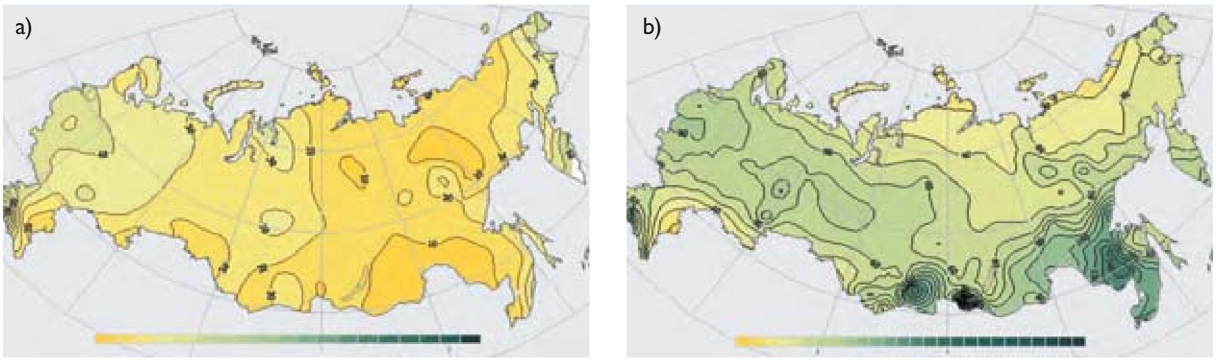


Fig. 1.5. Medium monthly total precipitation (mm) in winter (a) and in summer (b) for the period 1961-1990.
(After: Report on climate changes …2008)

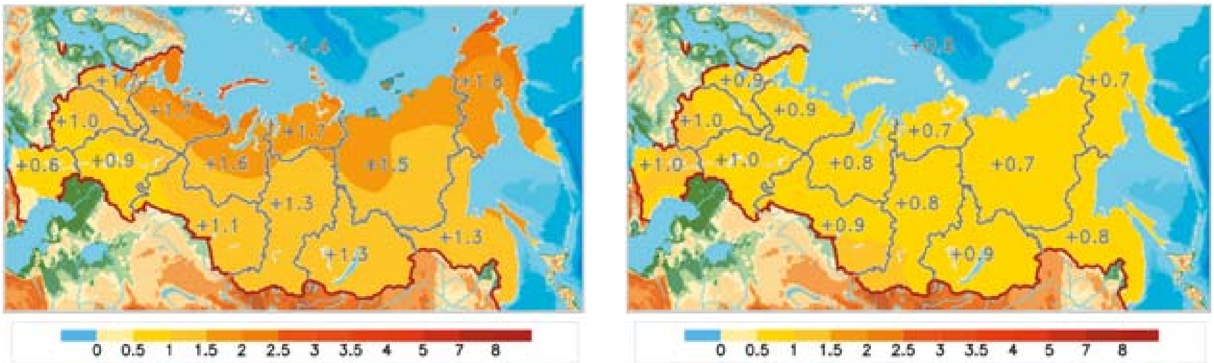


Fig. 1.6. Prediction of climate change 2011-2031. Air temperature (° C), (a) winter, (b) summer.
(After: Report on climate changes …2008)

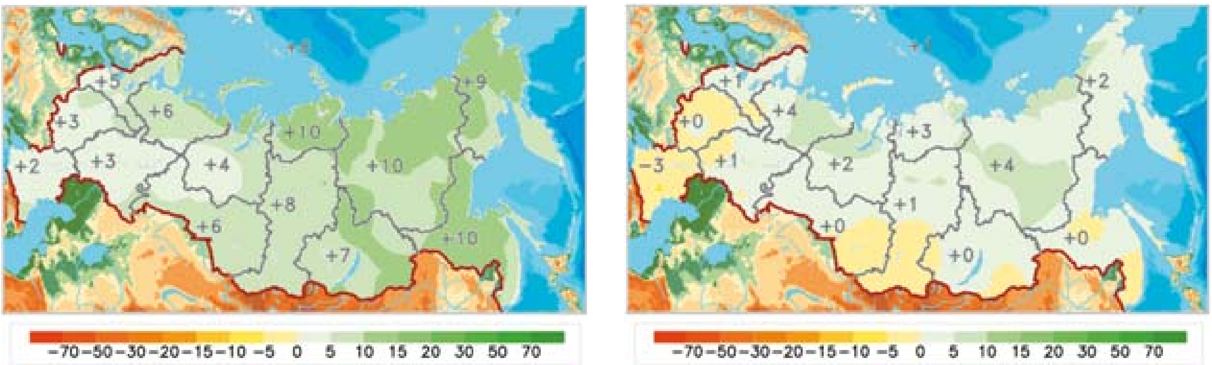


Fig. 1.7. Prediction of climate change 2011-2031. Precipitation (%). (a) winter, (b) summer.
(After: Report on climate changes …2008)

throughout the whole study area. This was especially pronounced in the east of the study area where the coefficients of the linear trends of wind speed were predominantly -0.3 to - 0.6 m/s during the course of 10 years (Report on climate changes... 2008). At present, highest wind velocities up to 34-38 m/sec are typical for the shores of the Barents and White seas. In these areas, northern forests are gradually being replaced by open heath ecosystems, with increasing wind velocities at their boundaries.

Thunderstorm activity is highest during the warm period, from May to August, though some thunderstorms are very occasionally observed in April; similarly, late storms have been reported in September and even in October. Winter thunderstorms are extremely rare. They are most frequent in July (4-6 days). In some years there may be up to 15-18 days with thunderstorms per month. On average there are between 10-17 days with thunderstorms each year throughout the whole study area.

Hail is not recorded in the study area every year and occurs chiefly during the warmer period from May to September, hailstorms being most common in June. They are usually accompanied by strong showers, thunderstorms and squalls. Their frequency (days per year) estimated over the long term is 0.6-2.1. Tornados (with wind speeds up to 40 m/s recorded) are extremely rare.

Thus, the climate of the study area is characterized by diversity due to the large extent of the territory, with considerable seasonal fluctuations in temperature and hydrological regimes. Murmansk Region lies in the area with the greatest fluctuations of meteorological variables over time. On the one hand, winter is relatively warm there, but air temperature can suddenly fall to -40°C near the coast and below -50°C in mainland areas. Cold spells may occur in any of the summer months and thaws in any of the winter ones. Mean daily temperatures below 0°C persist more than six months, making climatic conditions quite severe for living organisms.

Possible climate change in the study area could have both favourable and unfavourable effects on different species. Climate change would also affect the functioning and biodiversity of natural ecosystems. This should be taken into account in deciding strategies for nature protection in northwest Russia. Estimates of expected climate change effects in Russia for 2011-2031, in comparison with the period 1980-1999 (air temperature, total precipitation in forms of rain and snow) are presented in Fig. 1.6-1.7.

1.1.4. Hydrological characteristics

The main determinants of the hydrographic network in the study area are: the recent geologic origin of the network, the proximity to the surface of crystalline rocks and their lithology, the thickness of unconsolidated Quaternary deposits, the large number of tectonic dislocations, a rugged relief of glacial origin, high precipitation in combination with low evaporation, and the proximity of the main watershed to base levels.

The waters of the study area drain into both the Atlantic (via the Baltic Sea) and the Arctic Ocean (via the Barents and White seas), as well as via the inner basin of the Eurasian runoff into the Caspian Sea. The main watershed includes hills and ridges such as the Vetreny Poyas, Andoma, Veps, Kirillov, Vologda-Gryazovets and Galich elevations, and the Northern Ridges (Severnye Uvaly), which are situated chiefly in Vologda and Leningrad Regions and adjacent parts of the Republic of Karelia and Arkhangelsk Region. The rivers running north from the watershed (Onega, Northern Dvina, and Pechora) drain into the Arctic Ocean, whereas the western rivers (e.g. the Neva) drain into the Atlantic Basin. The southern rivers flow into the Volga and eventually into the Caspian Sea, which has no connection to the oceans.

Orographic characteristics, geological structure and deep faults determine the direction of flow. Most of the major rivers (e.g. the Northern Dvina, Onega, Sukhona, etc.) flow in low depressions formed by ruptures of the earth's crust.

Two major types of lake basins occur: tectonic and glacial, or morainic. Their distribution is determined by earlier relief formation processes and the effects of climate. The largest lakes (e.g. Ladoga, Onega, Vozhe, Lacha, Beloye (White) and Kubenskoye), situated in the zone of contact between the Baltic Shield and Russian Plate, were generated tectonically. Small and usually shallow morainic lakes are more common and distributed everywhere in areas of ice accumulation. They are especially numerous along the boundary of glaciation in the hills and hollows of morainic relief, which determines their paddle shape and (rounded) curving shoreline. Numerous floodplain lakes or oxbow lakes also occur along the course of all major floodplain rivers. They are confined to river valleys and have arisen as a result of separation from the main stream of sleeves, ducts or bends. Karst lakes occur in the southeast part of the study area. They are found in the basins of the Northern Dvina River

Table 1.2. Hydrological network in the studied area

Region/Republic	Rivers and streams		Lakes		Paludification, %
	Number	Density km/km²	Numbers	Lake surface: drainage area ratio, %	
Arkhangelsk Region	71 776	0.53	59 400	1.4	18.8
Vologda Region	20 000	0.48	4 816	3.1	12.6
Republic of Karelia	26 700	0.53	61 100	21	23
Leningrad Region	25 109	0.6	41 600	21	14
Murmansk Region	18 209	0.46	105 593	6.4	37

and the upper Volga due to the proximity to the surface of carbonate rocks. Few thermokarst lakes occur in the permafrost zone.

Arkhangelsk Region has a well-developed but unevenly distributed hydrographic network. Of its 71,776 rivers and streams, 94% are less than ten kilometers in length. Large rivers over 100 km long constitute only 0.2% of the total length. The river network is concentrated in three main water systems belonging to the rivers Onega, Northern Dvina and Mezen. More than half of the river flow is formed outside the region and enters its territory along the main rivers. Significant reserves of fresh water are concentrated in the lakes. Arkhangelsk Region has 59,400 lakes with a total area of 6,072 km^2. These lakes are unevenly distributed. The highest lake surface/drainage area ratio is in the western part of the Arkhangelsk Region, in the Onega Peninsula, the karst areas of the Onega-Severodvinsk watershed and in the White Sea-Kuloi Plateau. Small lakes with an area of less than 1 km^2 constitute 95% of the total number of lakes. The largest, Lake Lacha, covers an area of 354 km^2, in addition to which there are three lakes with an area exceeding 50 km^2, i.e. Kenozero, Kozhozero and Lekshmozero, all belonging to the basin of the River Onega. Arkhangelsk Region has several types of lake basins, the most common being glacial, karst, lowland and relic types. Glacial or morainic lakes (Kenozero, Kozhozero, etc.) are more common in the area of the last glaciation. Karst lakes are especially numerous in areas of gypsum karst, e.g. in the River Mehrenga basin, along the left bank of the lower stretches of the Pinega and in the upper basin of the Kuloi. Mire ponds are common within extended mire systems. Lagoon lakes are found along the White Sea shore. Salt lakes can be found in sites which contain salt domes, e.g. Lake Kuloi near Pinega village and Lake Solvychegodsk close to the city of Solvychegodsk.

Most rivers and lakes are at their warmest in July, when average water temperatures range from 14°

C to 19° C. In winter the water temperature in rivers and lakes is close to 0°C, though in karst areas with heavy inflow of groundwater it may remain at 1-4°C. The waters are completely frozen over for 160-200 days, on average. Ice conditions are generally determined by climatic conditions. The type of water supply of the rivers, the volume of water and, for the big rivers, also the flow direction can have a significant impact on the character of freezing.

The chemical composition of surface water and the concentration of different solutes in rivers and lakes in the area vary considerably over time and territory, due both to the changing seasons and the heterogeneity of the geological and soil conditions. Waters with high concentration of hydrocarbonates predominate (calcium is the dominant cation in almost all waters), chiefly characterized by small or medium values for the total number of inorganic ions.

Mires cover an area of 5,823,000 hectares. Wetlands exceeding 200 hectares constitute approximately 30% of the total number of mires in Arkhangelsk Region. On the mainland, these mires cover 5,800,000 hectares, making up 18.8% of the region's mainland area. Flat relief and the predominance of precipitation over evaporation, as well as the close proximity of impermeable soils to the surface, all promote the development of wetlands. According to materials from the Peat Fund of the Arkhangelsk Region, 73% of mires belong to the bog main type, 19% to the lowland fen type and 8% to the transition type.

Ground water in Arkhangelsk Region is found in a variety of forms. Location and properties are determined by the conditions of formation: the closer they are to the surface, the stronger their relationship with precipitation and surface waters; the deeper they are, the higher their mineralization. Permafrost areas of varying thickness are found in the north of the Mezen area, in the northeast corner of the Arkhangelsk Region.

Vologda Region incorporates altogether about 20,000 streams and rivers with a total length of more than 70,000 kilometers, together with over 5,000 lakes, eight of which are relatively large (surface area exceeding 25 km^2). Large artificial reservoirs have been created throughout the region, along the Volga-Baltic Channel crossing its western parts. The Belousov, Vytegra and Novinka reservoirs are found in the Lake Onega basin. The Kovzha and Sheksna reservoirs (including Beloye Lake), and part of the aquatoria of the Rybinsk reservoir lie in the basin of the Upper Volga River. Lake Kubenskoye, which is in fact an artificial reservoir, belongs to the basin of the Northern Dvina River. Mires cover 1,830,000 hectares or 12.6% of the total area of Vologda Region (State Report ... 2010b).

Andoma Hill on the shore of Lake Onega, remarkable as the best section of Devonian deposits in northern Russia. It is composed of multi-colored sandstone (laterite) and deserves attention due to the presence of the remains of fossilized trees and Devonian Crustacea. A nature monument called "Andoma geological cross-section" has been established here. This nature monument is also included in the protected Onega nature complex. Photo: Elena Belozorova.

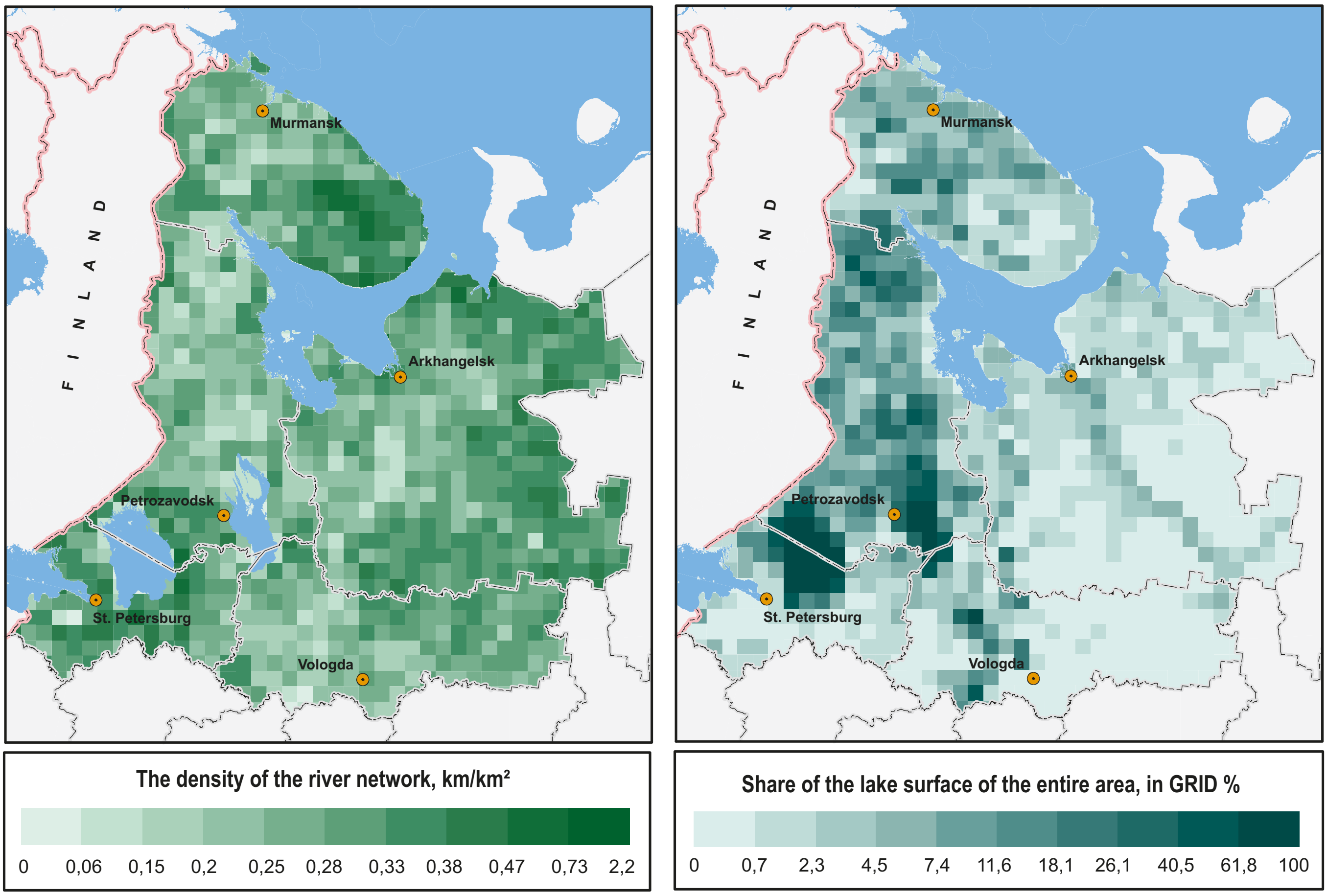


Fig.I.7. The density of the river network (left) and the lake surface/drainage area ratio (right) in the study area.

What comes to rivers, small streams and rivulets less than 25 kilometers in length predominate. The total length of these streams is more than 50,000 kilometers, or 72% of the total length of all rivers in Vologda Region. Rivers with a length up to 100 km constitute only 1.4% of the total number of all rivers and their share in the total length of rivers is 18%. Medium-sized rivers up to 500 km comprise less than 0.2%, and their total share of the total length of rivers in Vologda Region is equal to 8.5% (Nature of Vologda Region ... 2007).

Most of the territory of Vologda Region belongs to the basin of the White Sea. This includes rivers and lakes belonging to the systems of the two greatest rivers, the Northern Dvina and the Onega. More than half of this territory (49,500 km$^{2)}$ belongs, in its turn, to the basin of the River Sukhona, a left tributary of the Northern Dvina and to the basin of its right tributary, the River Yug. Joining together, these tributaries form the so-called 'Little Northern Dvina' which becomes the real 'Northern Dvina' after the inflow of the lower right tributary, the Vaga. The entire catchment areas of Lake Kubenskoye and the Vaga belong to the White Sea basin as well. The basin of the Baltic Sea occupies 5.7% of Vologda Region, in its northwestern part adjacent to Lakes Onega and Ladoga; the former accumulates water from the rivers Vytegra, Andoma, Megra, etc., the latter from the upper part of the Oyat River. The watershed dividing the Baltic basin from those of the northern seas and that of the Volga-Caspian Sea was probably formed during the final stages of the last glaciation and during the post-glacial period. The basin of the Caspian Sea occupies the whole southern part of Vologda Region, covering 37.6% of its total area. The Mologa, Sheksna and Suda rivers, as well as the upper parts of the Unzha and tributaries of the Kostroma and Vetluga, belong to the basin of the Caspian Sea (State Report ... 2010b).

The hydrographic network of the **Republic of Karelia** consists mainly of numerous small short streams and rivers which link lakes to form lake-stream or lake-river systems. Some of these, such as the Kovda, Lenderka and Kamennaya-Nogeusjoki systems, have lake surface: drainage area ratios as high as 50-60%.

Some 26,700 streams and rivers with a total length of 83,000 km have been reported for the whole of the Republic, including the Karelian Isthmus. 25,300 of these (95% of the total) are less than ten kilometers in length, their combined total length being 52,300 km. Only thirty rivers are over 100 km long (medium-length type). The average drainage density is 0.53 km/km^2. Most streams have small catchment areas. Only 366 water systems have basin areas in excess of 100 km^2, of which 51 systems have catchment areas of over 1000 km^2 and five systems (the rivers Kemi, Vyg, Kovda, Vodla and Shuya) have catchment areas of 10,000 km^2 or more. Rapids of various sizes, from sand spits and shallows to waterfalls, account for 80-90% of stream gradients. In some small rivers, e.g. the Neglinka, gradients are as high as 10 m/km, but gradients of 2-2.5 m/km predominate. In larger rivers, gradients generally are little more than 1 m/km but may also be higher over some stretches.

Narrow, low watersheds and the proximity of adjacent rivers, typical of Karelia, promote the transfer of runoff into other basins. Thus, the Suna discharges into Lake Palyeozero while the nearby Pongoma runs off into Lake Topozero. As the region has a rugged relief and major erosion bases are located close to watersheds, water flows out of lakes simultaneously in several directions (bifurcation). Thus Lake Engozero discharges along the rivers Kalga and Vonga, Lake Saarijärvi along the rivers Loimolanjoki (Tulemajoki) and Pensanjoki (Uksunjoki), and Lake Segezha along the rivers Obzhanka and Segezha, the latter being a tributary of the Swir (Biotic diversity of Karelia…2003).

Karelia has 61,100 lakes with a total area of some 18,000 km^2 (Gasheva 1967). In addition, approximately 50% of the aquatoria of Lake Ladoga and 80% of that of Lake Onega, the largest fresh water bodies in Europe, lie within Karelia. The Republic has a lake surface/drainage area ratio of 12%, a figure which rises to 21% if the Karelian portions of lakes Ladoga and Onega are considered. This is one of the highest ratios in the world. Lakes with a surface area of less than 1 km^2 predominate. Only 1,389 water bodies (slightly more than 2% of the total) are larger than this. Twenty lakes cover areas in excess of 100 km^2. Most small forest lakes and lakes of mire origin have no visible runoff.

Almost the whole of **Leningrad Region** lies within the Baltic Sea basin, except for the easternmost parts, which lie in the Volga - Caspian Sea basin. Leningrad Region has more than 1,800 lakes, the largest being Lake Ladoga (18,135 km$^{2)}$, also Europe's largest. The total length of all the streams in this region is about 50,000 kilometers, with Neva, Svir, Volkhov and Vuoksi as the largest.

Murmansk Region is the one of the richest regions of northwest Russia in terms of number of lakes and rivers, with over 110,000 lakes and 18,209 waterways longer than 100 m. Melt waters are the main source of their supply (up to 60% of annual flow). Annual spring floods last, on average, 2-2.5 months (May-June), after which rivers become very shallow.

The density of the river network is significant; its average value throughout the whole Murmansk Region is 0.46 km/km$^{2.}$ The total length of rivers exceeds 50,000 kilometers. On the northern slope of the watershed, facing the Barents Sea, the area of river basins constitutes, in total, 64,400 km^2, while those of the southern slope, facing the White Sea, total 80,500 km^2. A characteristic feature of the structure of the hydrographic network is the large number of small rivers. Thus, 95% of all the rivers are less than 10 kilometers in length. The total length of these streams constitutes 63% of the total length of all Murmansk rivers. The major rivers are the Ponoi (425.7 km), the Varzuga (262 km), the Tuloma (236.5 km), the Strelna (213 km) and the Iokanga (203 km). These, together with their tributaries, occupy about 70% of the total area of river basins of the Murmansk Region. Almost all the major rivers flow meridionally, only the Ponoi flowing east-west. Frequent rapids sections (sand spits, bars, shoals, rapids, waterfalls, etc.) alternate with large gentle stretches. Murmansk stream gradients are relatively high, averaging more than 1m per km of river. The rivers freeze for periods lasting up to 7 months, with permanent ice cover for, on average, 150-210 days a year. Opening of the rivers usually occurs in May.

Murmansk Region has, in total, 105,593 lakes and pools with an area exceeding 0.01 km$^{2.}$ Of these, 15,712 have a runoff. Lakes are more or less evenly distributed throughout the whole of the region, with average lake surface/drainage area ratio of 6%, though this varies between areas. For instance, in the basins of the rivers flowing to the northern Barents Sea coast, the lake surface/drainage area ratio is 6-11%, whereas in the basins of the rivers flowing to the White Sea it is only 3-8%. This ratio rises to its highest value of 21% in the basin of the Varzina. The largest lakes are Imandra (81,200 hectares), Umbozero (42,200 hectares), Lovozero (23,400 hectares), Pirenga (17,500 hectares), Kolvitsa (12,200 hectares), Kanozero (10,700 hectares), Sergozero (9,800 hectares) and Vyalozero (1,800 hectares). The majority of Murmansk's lakes (99%) are small, with an area less than 1 km^2, their average distribution being one lake per 1 km^2 of the land surface (Kola Encyclopedy 2009, State Report ... 2010a).

The water regime. The rivers of northwest Russia are supplied mostly by snow melt; on average, more than half the annual runoff (from 50 to 75% for the whole region of northwest Russia) is formed by melting snow. Snow is also the main supplier of the mountain rivers, but a combination of specific conditions, i.e. late snowmelt in conjunction with summer rains, can lead to summer floods which are particularly typical for Murmansk's mountain areas. Spring floods following snow melt also occur in some years on flat areas. The most dangerous spring floods, resulting from ice blockages and jams along large watercourses are observed in the rivers of the basin of Northern Dvina in Arkhangelsk Region.

In winter, all the rivers in Murmansk Region are frozen and have low winter flow. Snow melt coinciding with spring tides can lead to major flooding some years. The most dangerous floods occur along rivers of the Northern Dvina basin and associated with the formation of ice jams and watercourses under snow.

Changes in flow. Climate change, primarily the rise of air temperatures during the cold season with resulting frequent winter thaws, has a direct impact on river flow. Due to such thaws, soils are less deeply frozen, so a substantial portion of the water formed during thaws and spring snow melt does not contribute to river runoff but goes instead to increase the humidity of the active soil layer and groundwater replenishment.

Decrease in spring runoff is most pronounced in the rivers which flow via the upper Volga and its tributaries into the Caspian Sea (southeastern part of the Leningrad Region and western part of the Vologda Region). In recent decades the spring flow of these rivers has decreased by 10-20%. On the other hand, an increase in spring runoff by 15-25% has been observed in the more eastern Volga tributaries which are situated in the southeastern part of the Vologda Region. In the rest of the territory, no trend towards changes in spring runoff has been observed.

In winters the water content in the rivers increases throughout the study area. Generally, the trend towards increased winter runoff applies to most Russian rivers (Shiklomanov & Georgievsky 2007). In northwest Russia it is most pronounced in the upper parts of the basins of Northern Dvina and Volga (Vologda and southeast Leningrad Regions). In these areas, river water content during the cold season in 1978-2005 was, on average, 50-100% above the previous norm.

In the same period (1978-2005) summer-fall runoff also increased in the major part of the study area. The most significant increase in summer-fall runoff was observed south of 60°N, where the increase was 30-50% in most rivers. In areas north of 60°N, e.g. in the upper part of the Northern Dvina basin, the summer-fall increase was somewhat lower (20-

The Vytegra River valley in Vologda Region. Photo: Elena Belozorova.

25%). There were no significant deviations from the normal summer-fall runoff in the northernmost areas, like tundra, forest-tundra and northernmost forest zones.

Increasing runoff in most of the rivers during the period of lowest water levels ('mezhen' in Russian), i.e. during winter and summer low flows, indicates a significant change in the sources of supply, with increase of the underground components and decrease of the surface components. This may also be due to regulation of the natural flows. Increase of winter runoff during winter low flow in 1980-1990 led to increases in total water resources in the whole southwestern part of the study area, even in those river basins where a clear decrease in spring runoff and floods has been observed. Water content has increased most significantly in the tributaries of the Volga River (14%). Some increase in the flow into the Arctic Ocean has also been observed over the last 100 years, apparently due to rise of air temperature and the associated increasing frequency of winter thaws.

According to measurements obtained from water-balance stations (Georgievsky et al. 1995) the rise of the groundwater level reached 50-130 cm by the early 1990s.

The most significant increases in annual runoff (15-40%) have been observed in the rivers of the Leningrad and Vologda Regions that are located in the southern part of the study area, between approx. 56°N and 60°N and belonging to the Baltic and Caspian Sea basins and the Upper Volga. Further, during the period 1978-2005, the average annual runoff exceeded earlier values by 10-15% in the southern part of the basin of the Northern Dvina (Vologda and southern Arkhangelsk Regions).

Statistical analysis of long-term series of exact quantitative observations shows that the increase of annual runoff during the period 1981-2005 has, however, remained within the norm of fluctuations over a period of more than 100 years (Report on climate changes ... 2008).

1.1.5. Soil cover

The soils and land resources of **Arkhangelsk Region** are very diverse, which is explained by differences in climate, topography, landforms and soil-forming rocks, with corresponding vegetation, in different parts of its territory. Arkhangelsk Region extends over a large distance from north to south, through arctic (not in the study area), tundra and boreal forest bio-geographical zones. Soils within these zones belong to three groups according to their water supply: soil with normal moisture (automorphic); soil with temporary excess moisture (semi-hydromorphic); and permanently excessively moist soil (hydromorphic). Most of the region lies in the taiga-forest soil zone, which is characterized by the following main types of soil formation: *Podzols*, *Leptozols* and *Histosols* (henceforth soil names in this text correspond with the internationally accepted Guidelines for Soil Description, FAO 1990).

Podzol type of soil formation is most clearly expressed in the plains of the mainland on non-calcareous rocks covered with coniferous forests and their typical vegetation. They are characterized by a wash water regime (i.e. water permeates through them without stagnation). The leached podzolic layer on the surface is poor in nutrients. The composition of *Podzolic* soils can differ according to the type of exposed bedrock.

Leptosol type of soil formation, represented in the forest zone by *sod-calcareous*, *sod-gley* and *soddy-podzolic* soils, is less common, occurring chiefly on plains covered with herb-rich vegetation. This type of soil is characterized by the accumulation of humus and nutrients in the upper layer, which has a dark color and a well-defined structure.

Histosol types of soil formation, or boggy peats, are formed under semi-hydromorphic conditions on flat plains, in depressions and on bedrocks with low water permeability. They are the result of peat accumulation processes and gley formation on underlying mineral bedrock.

Floodplain soils occur in the floodplains of rivers and brooks. Their formation, in addition to zonal soil processes, is associated with the transfer and deposition of "nailok" (clay-sandy material carried in suspension) in periodic flooding.

Special types of soil formation are characteristic of arctic and tundra zones. In these areas, many soils of the *Podzol*, *Leptosol* and *Histosol* types occur, but in their subarctic variations.

Vologda Region has a variety of both soil-forming bedrocks and soil types, including *Podzols, Leptosols, Histosols*, *gley-podzolic*, *sod-podzolic*, *Gleyic Planosols* and floodplain soils (Plavinsky 2007).

Podzols or podzolic soils are the most common throughout the whole area. They occur wherever forest (in particular old coniferous forest) exists or has been recently felled, i.e. during the last decade. The thickness of the podzolic layer is largely determined by the composition of bedrock and also by the peculiarities of relief. Well-developed *Podzols*, so called strongly podzolic and deeply-podzolic soils, are distributed over non-calcareous bedrock in flat terrain; these soils are most frequently encountered in Vologda Region. Soils with medium and thin podzolic layers (medium and weak-podzolic) occur only on slopes of watersheds.

Leptosols, primarily *sod-podzolic* soils, are found on watersheds covered with sparse forest and in meadows. This kind of soil is more fertile than *podzols* so it is considered advantageous for agriculture, especially in the east and southwest of Vologda Region. Most of the *sod-podzolic* soils have been formed as a result of human activity, transforming former *Podzols* in the course of long-term agricultural use. Due to human impact to increase their fertility, upper soil layers have become enriched in nutrients, destroying the natural processes leading to the formation of *Podzols*. This also happens in cut forest areas after their transformation into meadows for use as pastures.

The distribution throughout Vologda Region of different subtypes of *sod-podzolic* soils depends on the type of bedrock. Soils with a high ratio of *Podzol* and low ratio of *sod* (strongly podzolic *Leptosols*) have formed on non-calcareous rocks, and are more common in eastern and northwestern parts. Soils with a more or less equal ratio of *Podzol* and *Sod* (medium podzolic *Leptosols*) are found on the slopes of watersheds and slightly carbonate periglacial and moraine deposits in the central part of the region, where they are confined to the vast lowlands, like the Vozhe-Kubenskaya and Sukhona lowlands. In the eastern part they are sparse. *Sod-calcareus* soils occur in areas of carbonate rocks or rocks rich in primary minerals. The most fertile *sod-calcareous* soils occur in the southwest parts, where bedrocks consist of carbonate moraine deposits. These soils are covered with rich grass vegetation, whose well-developed root systems favour the formation of a fairly thick humus layer. In general, all *sod-calcareus* soils in the Vologda Region are currently in agricultural use.

Floodplain soils are formed by rivers and lakes that are subject to seasonal spring and sometimes autumn flooding. Depending on their water supply they are classified as overmoist semi-hydromorphic and hydromorphic, of the following soil types: *sod-calcareous, gley-podzolic, sod-podzolic, Gleyic Planosols* and *Histosols.* Floodplain soils are common at the mouths of big rivers such as the Mologa, Sukhona, Vologda, Yug, etc., and on the lower terraces of Lakes Vozhe and Kubenskoye. Floodplain soils are very diverse in texture and chemical composition.

Among the hydromorphic soils *gley-podzolic soils* and *Histosols* are the most common soil types in the region. They form on poorly drained land supplied with ground water. They are most widespread in the northern and eastern areas of Vologda Region.

The soil cover of the **Republic of Karelia** consists of macro and mesocombinations of *Podzol*, *Cambisol*, *Gleyic Podzol, Histosol* and *Leptosol* types. The variety of landforms and soil-forming rocks occurring in Karelia results in a soil cover mosaic of complex combinations. A moderately cold and humid climate, the predominance of light soil-forming rocks and the prevalence of conifers in forest cover are conducive to the large-scale formation of eluvial-illuvial soils in automorphic environments. Different types of *Podzols* (60.8%) cover Quaternary sediments; *Cambisols* (0.9%) occur on eluvial-deluvial rocks or on moraine rich in these rocks; *Haplic* and *Litic Leptosols* (0.8%) or poorly developed soils (1.3%) accumulate on bedrock. As Karelian soils are of fairly recent genesis, almost no crystalline rock eluvium has formed and the primary soils beneath lithophilous plants growing on massive crystalline rock exposures are very thin. Various types of *Gley Podzol* soils are formed under semi-hydromorphic conditions. *Podzols* and *Gley Podzols* are dominated by their sandy and loamy sand varieties. Loamy and argillaceous soils make up less than 6% of the Karelian land surface. *Fibric Histosols* (10.8%) and *Terric-Fibric Histosols* (8.2%) are of widespread occurrence. *Terric Histosols* make up not more than 1% of the total land area (Biotic diversity … 2003).

There are some differences in soil-forming processes and soil cover between boreal forest sub-zones (generally, northern boreal and middle boreal forest soils are slightly less productive than southern boreal forest soils), as well as between different areas within the sub-zones. In the northern boreal and middle boreal sub-zones the formation of soil cover is profoundly affected by the proximity of the White Sea. The present transgression and regression of sea water and the associated moisture content of soils in the tidal zone has contributed to the formation of unique alluvial saline moisture soils, or *Salic Fluvisols*. These soils are rich in chlorine, sulphur and water-soluble mineral substances, atypical for the podzol soil zones. They contain high percentages of organic matter throughout the entire profile because mineral layers alternate with algal laminae and display a high degree of biodiversity. On the White Sea coast *Salic Fluvisols* alternate with primitive soil types on bedrock outcrops. Primitive soils occur only under sod cover bearing herb-rich vegetation or under forest litter in open pine forest.

Epi-Histic-Gley Podzols are of common occurrence throughout the middle boreal forest sub-zone, where they occupy not only topographic lows (such as those in the southern boreal forest sub-zone) but also the flattened tops of morainic ridges and hills. This is due to the proximity of crystalline rocks which impede the free filtration of moisture. Furthermore, the occurrence of coarse soil-forming sandstones contributes to the development of a humus-illuvial process.

Hapto-Lithic Podzols and *Lithic Leptosols* appear in hilly areas where a clear pattern of vertical zoning occurs. These mountain soils are generally poorly understood. In Karelia they are very rare, found only in the northwestern part, where some ridges reach altitudes of up to 600 meters asl.

Gley Podzols in complex with *Histosols* cover over 40% of the northern boreal and middle boreal forest sub-zones due to cold climate, poor evaporation and a consequently high moisture coefficient. *Histosols* are dominated by a bog peat soil (*Fibric Histosols*) which accounts for 14% of all soils, with fen soils (*Terric Histosols*) occurring as individual mire-systems. Raised bogs in Karelia cover an area of about two million hectares. *Histosols* that have evolved on bogs are infertile and poor in micro-organisms, inhibiting the transformation and mineralisation of organic matter.

In the southern boreal forest sub-zone, owing to better climate conditions, soil-forming processes are active to a depth of 1.5-2m. Automorphous soils are more extensive while *Gley Podzols* and *Histosols* are only half as common (22%) as in the northern- and middle boreal sub-zones (40.5%).

Podzols make up two thirds of the soil cover in the southern boreal sub-zone and are therefore the most common soil type in the whole of the republic. They form on bedrocks poor in bases and ferruginous minerals and may vary widely in their mechanical composition and genesis. For example, *Podzols* may form on glaciofluvial and lake sand, on sandy or loamy sand moraine deposits. They all contain small percentages of silt and mud particles. Moraine deposits are heterogeneous and bouldery. The other factor influencing the process of formation of such soils in Karelia is the abundance of coniferous forests. The bulk of organic remains consist of ground litter-fall which is poor in ash elements and nitrogen. A lack of bases and an acid reaction, together with certain biochemical characteristics of plant remains, e.g. high percentages of resin, wax and lignin, result in a poorly developed microflora and the slow humification and mineralization of litter-fall. The litter reserves on the soil surface are 5-20 times that of annual tree waste.

In Zaonezhye Peninsula which is situated on the northern coast of the Onega Lake, limestone and carbonate rocks contribute to the development of *Shungite Cambisols*, a unique soil type which evolves on carbonaceous shale eluvium. These soils are called “the Olonets Chernozems” because of their typical black color and high natural fertility (The study of forest soils in Karelia 1987).

In **Leningrad Region** podzolic soils predominate as in the areas to the north, but the mosaic diversity of soil is higher here, resulting from the heterogeneity of the geological structure, the composition of the soil-forming rocks and the climate. The main soil types can be listed as follows: weakly podzolic, superficially podzolic (or cryptopodzolic) soils form on sand and sandy loam in the hilly-ridge areas; *Humic-illuvial Podzols* occur in the low usually overmoist sandy plains and terraces; *Gley Podzols* form on clay and sand-clay moraine deposits. In the Karelian Isthmus, soils on granite bedrock outcrops are thin and stony whereas in clay and moraine deposits they usually have a pronounced humus layer. The Ordovician plateau consists mostly of carbonate rocks and therefore has highly fertile *Sod-calcareou*s soils on limestone, which generally are typical in more southern parts of Russia. Besides podzolic soil types, *Histosols* are widespread throughout this region, wherever moisture is excessive.

In **Murmansk Region** the dominant types of soil formation are *Podzols* and *Histosols*. Podzolic soils formed in sandy rocks of continental and marine origin differ markedly in content and reserves of humus and nitrogen. *Illuvial-Ferruginous Podzols,* a type of podzolic soil generally poor in organic matter, occur in dry pine forests with lichen and shrub-lichen ground vegetation. *Illuvial-Humic-Ferruginous Podzol*s, which are richer in humus, occur on slopes covered with pine- and spruce-dominated forests with a well-developed dwarf shrub understory. *Humic-Illuvial Podzols,* characterized by thick litter and a considerable amount of humus in both the podzolic and the illuvial layers, occur in moist areas with a mixture of spruce-birch forests with dwarf shrub understory and a thick layer of mosses. *Terric Histosols* developing on peatlands have a thick (>20 cm) organogenic peat layer with high humus content.

In the tundra and forest-tundra zones, *Humic-Illuvial Podzols* are usually rich in organic matter. Soils in the alpine tundra and in mountain forest are also high in humus in the mineral strata. On the coast of the Barents Sea, primitive peaty soils with separate humus layers and undifferentiated mineral layers are the least fertile type.

Soils of greater particle size occur mainly in the valleys of large rivers flowing into the Barents Sea. The distribution area of these soils is extremely small, and for this reason they may not be reflected in the small-scale map. Peat soils, or *Fibric Histosols,* are found everywhere, in all natural zones. Depending on the botanical composition of the peat they are divided into transitional peat soils (*Peats, transitional mire*) and bog soils (*Peats, raised bog*). Transitional peat soils are composed of grassy, herbal and hypnum-woody peat, while bog soils consist mainly of the remnants of sphagnum moss.

Generally, the soil cover of the Murmansk Region is characterized by great diversity and complexity, due to the variability of soil formation conditions in rugged terrain. These soils are in the main overmoist and, as a consequence, they have a large heat capacity (Ecological Atlas ... 1999, Belov & Baranowska 1969, Nikonov & Pereverzev 1989, Yakovlev 1961).

1.1.6. Vegetation. Biomes

The study area in northwestern European Russia is located in two biomes: Eurasian tundra and Eurasian taiga. Taiga, mainly corresponding to the boreal coniferous forest, is a basic biotic constituent. As a consequence of the meridional extent of the study area, there exist differences in the composition of forest vegetation, particularly noticeable between its northern and southern parts. According the unified system of bio-climatic vegetation zones by Ahti et al.(1968) and Hämet-Ahti (1981) forest covered land in northwest Russia is divided into the following belts of vegetation: northern boreal, middle boreal, southern boreal and hemiboreal forests (see Fig. 3.6, p.130). Mires of different types are distributed throughout all these divisions.

As a result of industrial use of forests in places like northwest Russia, such natural landscapes have become rare. Murmansk Region, the planned protected area "Kaita". Photo: Gennady Aleksandrov.

Each region is divided into geobotanical provinces according to the type of vegetation. The timberline in the Murmansk and Arkhangelsk Regions is situated between 67°20′ N - 66° N. The northernmost forests with sparse growth of trees adjacent to tundra in Murmansk and Arkhangelsk Regions are included in the Kola-Pechora subprovinces of the North-European taiga. In Arkhangelsk Region they are found on the White Sea shores, along the Abramov Shore and the Konushinsky Shore of Mezen Bay, as well as along the shores of the Mezen River, near its mouth. These forests are characterized by alternation of sites covered by forest and tundra communities. Forests here are generally of low density (0.1-0.3). The ground cover is made up of macrolichens mixed with green moss and dwarf shrubs. Spruce-dominated forests here belong chiefly to *Polytrichum, Cladonia,* and *Sphagnum* groups of forest types. Spruce-dominated forests of *Polytrichum* group occur in the middle parts of the predominantly gentle slopes with southern exposure on sandy loam soils, those of *Cladonia* group are confined to the lighter sandy soils, whereas those of *Sphagnum* group grow on water logged soils.

In taiga biome coniferous forests prevail, accounting for 78% of the forest covered land of the study area. Of these, 'dark' taiga consisting of spruce stands occupies more than 51%. Pine-dominated forest stands cover 27.0%. Of the deciduous forests, which occupy 22% of the forested area, birch-dominated forests account for 93%, while aspen, alder and willow-dominated forests occupy the remaining 7%. Spruce-dominated forests in the northern boreal and middle boreal forest sub-zones consist chiefly of green mosses (*Pleurozium, Hylocomium*, *Polytrichum)* and *Sphagnum* groups of forest types.

Pine forest of *Cladonia* type. Arkhangelsk Region, "Shilovsky" protected area. Photo: Artyom Stolpovsky.

In the southern boreal and hemiboreal forests green mosses forest types (e.g. *Hylocomium-Myrtillus* type) prevail. A similar division into forest types exists in pine-dominated forests, viz: green mosses and *Sphagnum* groups with the addition of the *Cladonia* group are most common in the northern and middle boreal forest sub-zones, with green mosses and *Sphagnum* groups mainly in the more southern areas.

Natural patterns of distribution of different forest types are mainly due to soil conditions. The dark coniferous forests are confined to upland locations. Larch-dominated forests need fertile soils on limestone and gypsum bedrock, thus occurring chiefly in restricted areas. Pine forests grow mainly on the sandy terraces in the valleys of major rivers. There is no definite pattern in the natural distribution of secondary forests dominated by aspen, birch and grey alder. The present distribution of forest types may result also from the anthropogenic transformation of the territory. Large pine-dominated forests often have pyrogenic origin. Distribution of secondary deciduous forests (with the exception of birch-dominated natural forests beyond the conifer timberline or on wetlands, or alluvial areas, and deciduous forest developed after natural fires) in northwest Russia is unnaturally wide, and is a consequense of former forest-cutting activities.

Mires play a significant role in the characteristics of vegetation cover of the study area. *Sphagnum* bogs predominate, but there are also other mire associations: sedge associations, sedge-*Sphagnum* associations and mires with grasses and Bryales mosses. Meadows are present chiefly as dry grasslands, floodplain wet grasslands and sea coast grasslands.

With the melting of the last glacial ice sheet several thousands years ago, vegetation started to invade suitable areas. In **Murmansk Region** this process started some 12,000 years ago. Plants gradually migrated north, with mosses, grasses, some species of *Betula*, *Cladonia* and *Empetrum* among the first. They formed tundra, forest-tundra and meadow communities. As the ice receded (9000-10,000 years ago), the plant cover took on its current shape, with clear zonation into tundra, forest-tundra and boreal forest biomes. The tundra zone formed in the north, the forest zone was originally dominated by birch. Further warming led to invasion by Scotch pine, *Pinus sylvestris* (boreal climatic period). During the period of favorable Atlantic climate, pine and mixed forests reached the coast of the Barents Sea. A new cold period 5,200 years ago (sub-boreal climatic period), accompanied by glaciation in mountain areas, led to a deterioration of conditions for the growth of forests. Together with further human impact (e.g. deforestation due to cutting and human induced forest fires) this led to a retreat of the forest zone to the south and the appearance of specific relatively poor tundra communities in the northern areas of the Kola Peninsula. Thus, at present there are two major biomes, tundra and northern boreal forest represented in Murmansk Region.

A fragment of natural broadleaf deciduous forest near Koporye village, Leningrad Region. Photo: Olga Volkova.

The shrub tundra communities dominate on the coast of the Barents Sea. Further inland shrub tundra is replaced by lichen-shrub and lichen-tundra, with dwarf birch (*Betula nana*) and shrubs like *Empetrum*, *Vaccinium uva-ursi, Vaccinium vitis-idaea*. In tundra communities to the south, the basic vegetation is formed by willows and dwarfs. Willows (*Salix* spp.) grow usually on steep slopes and in depressions. The ground cover there includes certain species of sedges (*Carex*), grasses, and herbacious species such as *Trollius*, *Geum*, *Filipendula, Pedicularis*, *Potentilla*, *Comarum*, *Myosotis*, *Swida* and *Geranium*, and *Sphagnum* mosses.

Forest, including forest-tundra, covers about 80% of Murmansk Region. Of this, only 23% is northern boreal forest, the rest being composed of various types of forest-tundra associations, mires covered with sparse tree-cover, and lakes. Among forest-tundra vegetation types the most typical are sparse *Betula pubescens* ssp. *czerepanovii* forests, with ground cover consisting of shrubs, green mosses and lichens. The understory is usually formed by juniper and dwarf shrubs and, in some places, sparse *Cotoneaster cinnabarinus* and willow shrubs. The average height of *Betula pubescens* ssp. *czerepanovii* gradually decreases from 6-8 m of the northern boreal mountain-birch forest to 1.5 m when moving north.

The taiga biome is mainly represented by associations typical of the northern boreal forest sub-zone. Through the influence of westerly winds, Murmansk's climate in its western areas is milder than in the east. As a result, taiga here spreads further north than in the eastern areas. Forests are spruce, pine and birch-dominated. Spruce-dominated forests are more common in the east and north, whereas pine dominates in the west and south. Both spruce and pine-dominated forests incorporate an admixture of birch, which may in many places compose half of the stand. Mixed spruce-birch forests are mostly of *Hylocomium-Myrtillus* or *Cladonia* types, or a mixture of both. Pine-birch forests are mostly of the *Cladonia* type. Dwarf-shrub vegetation is almost absent, with only juniper and dwarf birch present in minor fractions. Pure willow, pure birch and spruce-birch forest with grass cover are distributed along river valleys.

Mires cover 37% of the entire region. The most widely developed are ridge-pool bogs and fens and palsa mires, which are characterized by peat mounds of permafrost, thawing in summer to a depth of 30-55 cm.

Tundra biome. Mountain tundra on the shores of the Barents Sea, Murmansk Region. Photo: Gennady Aleksandrov.

In the mountains and hills vertical zonation is well-developed. With increasing altitude, boreal forest associations are replaced by birch-dominated forest-tundra associations. Trees are sparse, the intervals being covered with lichens, which cover up to 40-70% of the area. Alpine tundra associations appear above the forest and forest-tundra belts, on average above 350-400 m asl (on northern slopes 50-100 m lower). On the lower slopes (ca. 400-600 m asl) shrub and shrub-lichen tundra prevail. Higher (up to 700 m asl), they are replaced by small shrub-lichen tundra. Above 700 m, alpine tundra with sparse vegetation and limited species of moss and lichen is located. This mountain tundra covers 1-5% of the area. The remainder is characterized by boulder streams and fields without mosses or vascular plants. Only epilithic lichens occur on these rocks (Ecological Atlas ... 1999, Ramenskaya 1983, Red Data Book of Murmansk Region 2003, Kola Encyclopedy 2009).

Arkhangelsk Region, owing to its large extent from north to south, is characterized by a well-defined zonation of natural vegetation. Three main biomes are represented here: Arctic deserts, tundra, and boreal forest zones. Mires and grasslands are found in all the biogeographical zones.

Plant communities typical of Arctic or polar deserts are found on the greatest islands of the Arctic Ocean: the archipelagoes of Franz Josef Land, and Novaya Zemlya-Severnaya Zemlya, with a number of other smaller islands. All of them are situated north of the study area. All tundra sites in the study area belong to the southern tundra community type. Tundra with well-developed layers of mosses and lichens prevail.

Forest consisting of mountain birch *(Betula pubescens ssp. czerepanovii)*, Volshebnyi (Magic) Island in Lake Lovozero, Murmansk Region. Photo: Gennady Aleksandrov.

The biggest single water-basin mire complex in Europe, in the basin of the Ponoi River, Murmansk Region. Raised bog – left, aapa mire – right. Photo: Aleksey Veselov.

Forest land covers 78% of the whole land surface of the Arkhangelsk Region mainland (i.e. excluding the islands in the White Sea and Barents Sea). Western, southern and central areas up to the Northern Dvina river in the north, which have undergone intensive logging, are characterized by a significant proportion of secondary forest; both naturally formed mixed forests and planted managed pine forests. Enormous large old-growth forests still exist in several parts of Arkhangelsk Region, mostly in its northern part, e.g. on the Onega Peninsula; in the area between the rivers Pinega and Northern Dvina; near the cities Berezniki and Krasnoborsk; in the Leshukonsk area; and also in the eastern parts of the Pinega and Verhnetoemsk administrative units. These forests, with their natural structure and composition, harbour many typical forest plants and animals now rare and endangered in Europe. In southern and central parts of Arkhangelsk Region, natural forest occurs only as fragments less than 10,000 hectares in size.

The flora of Arkhangelsk Region is characterized by great species richness. There are over 1300 species of higher vascular plants, of which 316 are considered rare and endangered. In terms of geobotanical characteristics, the local flora is heterogeneous. More than 60% of the species have boreal distribution. Of these, Palaearctic boreal species are widely distributed throughout the territory while the European boreal species are more typical in the western part of the Arkhangelsk Region. Siberian boreal species are distributed mostly in the eastern part. Subarctic, arctic and arcto-alpine species together constitute ca. 25-30% of the whole species pool of vascular plants. Nemoral species (5-8%) are confined to broadleaf deciduous forests in the south, while a few species typical of steppe (resembling American prairie), like the forest anemone (*Anemone sylvestris* L.), make up less than 1%, occurring only in dry pine forests and on steep, rocky river banks.

Vologda Region lies entirely within the taiga zone, in its two southernmost sub-zones, the middle taiga or southern boreal sub-zone characterized by the prevalence of spruce-dominated forests of *Hylocomium-Myrtillus* type, and the southern taiga or hemiboreal forest zone characterized by the prevalence of spruce-dominated forests, which are usually of *Oxalis* type or *Myrtillus* type with oak (Nature of Vologda Region 2007). The borderline between these two zones was originally situated along the 60th parallel, deviating to the north on the sites on sod-calcareous soils on limestone. At present this borderline is not so evident because the original forests have been almost entirely logged and replaced by secondary mixed forests with similar composition. The northern limits of the natural distribution areas of many broadleaf trees like oak, maple, hazel, etc. are situated in the south of Vologda Region. Elm-dominated forests and forests with elm still exist in the Sukhona and Vozhegod lowlands along the floodplains of the rivers Sukhona and Vozhega.

Previous to massive logging, coniferous forests dominated, with mainly Norway spruce (*Picea abies* (L.) Karst.) in the western part, and Siberian spruce (*Picea obovata* Ledeb.) in the eastern part (Pravdin 1975). In both parts, the *Hylocomium-Myrtillus* type was predominant, constituting ca. 50% of all spruce forests. Pine-dominated forests cover, at present, about 20% of the forested area. They are present as *Sphagnum* and *Polytrichum* types growing on swampy lowlands of the southwest and have a low productivity. Birch-dominated forests prevail among the mixed forests formed everywhere on logged areas and abandoned agricultural lands. Forests dominated by aspen and grey alder are considerably less common but also widely distributed as small fragments. Deciduous forest dominated by common or black alder (*Alnus glutinosa*) and willow are rare.

Vologda's mires cover extensive areas within the lowlands and poorly drained upland watersheds. In total, mires constitute 12% of the whole area, their proportion in western and northwestern parts rising to 40%, while in the southern and eastern parts they cover ca. 2%. Oligotrophic bogs and complex mire systems on the Mologa-Suda lowland between the rivers form the most extended mire units.

Natural grasslands comprise about 7% of the Vologda area and have a great variety, including more than 50 meadow formations (Red Data Book of Vologda Region 2003, 2004).

The **Republic of Karelia** lies entirely in the boreal forest zone. Extending over 650 km from latitude 61° N northwards as far as the Arctic Circle, Karelia's bioclimatic sub-zones vary from the middle boreal to the southern boreal sub-zone with some northern boreal areas on the highlands in the northwestern past of the republic. The boundary between the first two lies approximately along latitude 63°N. Forests cover about 70% of the whole republic, with pine-dominated forests forming about two thirds of the forested area and especially common in the northern part (Biotic diversity ... 2003). They grow in a variety of forest site types ranked from lichen (*Cladonia*) types on dry sand and rubiginous soils to paludified pine forest types on *Sphagnum* bogs. The most productive forest types, occurring only in the southern part of the republic, are those of the green mosses group represented by *Myrtillus* and *Oxalis* types. *Myrtillus* types are represented by both pine- and spruce-dominated stands, those of the *Oxalis* type are chiefly spruce-dominated.

Spruce-dominated forests cover about one third of the forested land in the Republic of Karelia, mainly in its southern part, around Lake Onega and in the Karelian parts surrounding Lake Ladoga. In some sites they include some broadleaf deciduous trees. In northern Karelia, spruce-dominated forests are sparser, with poor composition of the ground vegetation. Deciduous forests formed mainly after clear-cutting cover ca. 10% of the forested land in the Republic of Karelia. As in other northwest Russian regions, they are chiefly birch-dominated, though a few stands are dominated by aspen and grey alder.

Mires, widely distributed in Karelia, are the second most abundant type of land cover after forests. They are present in great variety, including almost all the mire types that occur in the northern boreal zone. The most widespread are ridge-hollow and ridge-pool raised bogs. Very often mires contain a combination of different types, with patches of *Sphagnum*, dwarf shrubs, forested or treeless fens, aapa mires, etc. Spring mires are more common in the eastern part of Karelia. Mires are found not only in depressions and on flat surfaces, but also on steep slopes, where a weak downhill flow of water can be observed (Red Data Book of Karelia 1995).

Leningrad Region lies within the southern boreal and hemiboreal forest sub-zones. 55.5% of its territory is covered by forests. The vegetation of the southwestern parts of the region and the Ordovician plateau is similar to that of the temperate (nemoral and boreo-nemoral) forest where broadleaf trees are widespread, together with their accompanying understory of bushes and herbs. The spruce-dominated forests which covered most of the territory prior to vast logging operations are still the primary forest type here. The most common type of spruce-dominated forest belongs to the green mosses group and, within this group, to *Myrtillus* and *Oxalis* types. Herb-rich spruce forest stands sharing many grass species with broadleaf decidious forest are very notable, particularly in the southwest, on the Ordovician plateau. Pine-dominated forests are also very common in Leningrad Region, represented by various types of the *Pleurozium* and *Hylocomium, Cladonia, Polytrichum* and *Sphagnum* groups. The Karelian Isthmus is characterized with its pine forests of the *Empetrum* type, which are mostly found in the study area much further to the north.

Broadleaf deciduous forests are found mainly in the southwestern parts with small fragments confined to the main river valleys, on the slopes of the Baltic-Ladoga Scarp and along the shores of large lakes. These fragments are usually dominated by elm (*Ulmus laevis* & *U. glabra*), ash (*Fraxinus excelsior*) and small-leaved lime (*Tilia cordata*). There are also fragments of forests dominated by small-leaved deciduous trees as birch (*Betula pubescens & B.verrucosa*), aspen (*Populus tremula*) and grey alder (*Alnus incana*), which are classified as belonging to different forest types according to their ground vegetation. Forest patches dominated by black alder (*Alnus glutinosa*) occur on moist places with springs, and on black alder swamps mainly along the coasts of the Gulf of Finland and Lake Ladoga. These forests are very special in their vegetation pools because of the presence of many rare species with high environmental demands. Juniper (*Juniperus communis*) communities situated on dunes of Lake Ladoga and on the Ordovician plateau are also of great interest due to their peculiarities.

Large areas of Leningrad Region are covered by mires. The most widespread are ridge-hollow and ridge-pool raised bogs. *Sphagnum* raised bogs with pines (without pools or hollows) are to be found less frequently. Various kinds of mires of the transitional type are widespread throughout the region. There are also spring fens similar to northern-type mires in their vegetation. Spring fens on limestone bedrock, occurring chiefly at the margins of the Ordovician plateau, are a very specific group in their vegetation, with a unique range of rare plant species.

Meadows occupy only a small area of this region. The coastal meadows harbour very specific pools of plants called halophytes and psammophytes, strictly confined to sandy dunes. The vegetation on calcareous and granite rock outcrops, where rare species of ferns are to be found, is also of considerable interest. Rich aquatic vegetation is represented by a large variety of marine and freshwater plants.

1.2. Human influence to nature in northwest Russia

1.2.1. History of land use

Colonisation. About 17,000-20,000 years ago, the territory of modern northwest Russia in its northern part was still occupied by the last glacial ice sheet. The northern timberline was situated along the line Smolensk-Vologda-Mezen, i.e. the major part of the territory of northwest Russia covered nowadays by boreal forests, was then mainly open landscapes recently freed by the melting of the glacial ice. As the ice receded, ancient man moved in following animals which, in their turn, had followed plants invading suitable areas as they appeared after the melting of the ice. According to archeological data, colonization of the territory had been started by half-savage Mesolithic tribes and continued by more recent tribes gradually moving in from the southwest. Paleolithic records of human activity have been found about 64° N, in the territory of the current Kholmogory municipality along the shores of the Northern Dvina River. These were only temporary summer sites occupied by hunters, who reached these high latitudes moving along the rivers. Permanent settlements of the ancient peoples were situated further south, with around 62° N as their northern limit. More intensive colonisation of the territory started after the end of the last Ice Age when the ice sheet melted and vegetation appeared. In Murmansk Region the first sites showing traces of ancient man have been found in the Rybachy Peninsula, dating back 11,000 – 12,000 years, i.e. to the end of the Pleistocene. In the Republic of Karelia the earliest sites found on the northern shore of Lake Onega date back to 9,000-10,000 B.C. These ancient peoples were attracted by the indented shoreline with numerous fjords and islands which, in combination with rivers and numerous small lakes, created habitats rich in fish and wetland animals. Pine-dominated forests rich in berries, mushrooms and game provided a hunter-friendly environment. In Arkhangelsk Region, Mesolithic settlements from the same period have been found in many places along the shores of the big rivers, e.g. the Northern Dvina, Vychegda and Pinega. Using these waterways was the only way for these ancient people to move into and settle new territory. The oldest Mesolithic settlements, dating back to 7,000-9,000 B.C., were found on shores of the River Pinega, close to where the village Karpogory is situated at present.

During the most favorable Atlantic climate period of the Holocene (7,000 – 4,000 years B.C.), the north-

The abundance of scenes portraying the hunting of sea animals in petroglyphs dating from the Neolithic and the Early Metal eras indicates the orientation of livelihood at this time, primarily marine hunting and coastal fishing. On the other hand, the emerging themes of hunting for reindeer, bear and other forest animals indicate the early development of hunting in inland areas. These rock drawings were found on Stone Island in Lake Kanozero, Murmansk Region. Photo: Gennady Aleksandrov.

ernmost areas of northwest Russia, e.g. the Kola Peninsula, were also being gradually invaded by man. Forest cover changed significantly: during the course of the first half of the Atlantic period the Kola Peninsula was covered chiefly by pine-dominated forests, whereas spruce-dominated forests appeared and became widely distributed there during the course of the second half of the Atlantic period. Generally, the Atlantic period is characterized by wide distribution of settlements confined to coastlines not only in northwest Russia but throughout the whole of northern Europe, from Britain in the west to the Novaya Zemlya archipelago in the east. This period was characterized by diversification of the archaeological cultures. The archaeological cultures of river- and lake-fishermen and hunters gradually diverged from the coastal marine sector, although close relationships between all these archaeological cultures remained relatively strong. Around this same time, a transition from the Neolithic era to the Early Metal era took place, which was related to more intensive use of fire. The youngest stone labyrinths on the coasts date back some 3,000 – 4,000 years. This indicates a gradual re-orientation of activity towards land use, and a reduction in the importance of maritime transportation and economy in that period. Stone labyrinths found in the Solovets archipelago of the White Sea were built during the period 3,000 – 2,000 B.C. At the beginning of the new era, Finno-Ugric peoples from the Urals became the dominant ethnic groups in what is now modern northwest Russia.

A new cooling 5,200 years ago (the sub-boreal climatic period) led to further changes in forest composition, with previously dominant dark conifers decreasing, and light conifers and small-leaved deciduous trees correspondingly increasing. Traditionally, this is explained by the deterioration of conditions for the growth of forest due to general cooling, but this was not the only reason. Another factor was chiefly anthropogenic, frequent forest fires which accompanied the process of colonization of the inner mainland areas by man. Some thousand years ago, hunting of wild reindeer was first combined with, and then significantly replaced by, the domestication of reindeer. This influenced the distribution of the early inhabitants; they could now move away from the big lakes and rivers inland to areas suitable for reindeer grazing. This process can be traced on the basis of archeological data; the coastal settlements did not disappear, but in addition to them, the new, generally younger, settlements appeared, often far inland from water bodies. Most of these settlements were just temporary seasonal sites. The only exception is the eastern part of the Kola Peninsula, where the first domesticated reindeer farms appeared only in the 18th century. Before this time, only hunters and fishermen lived in this area.

During the course of the period 5,000 – 2,000 B.C., a new type of archeological culture of hunters and fishermen, called "The Kargopol culture", appeared and spread widely along the shores of the White and Barents Seas and their islands, and on the shores of three big lakes, Lacha, Vozhe, and Kenozero.

The earliest written Russian documents containing information about the people inhabiting northern areas date from the 12th century. According to these documents, the forest zone was colonised by Finno-Ugric peoples, whereas the tundra was inhabited by Lapps (Saami people) and Nenets (a Samoyed tribe) (Pomor Encyclopedy 2001).

Pomor villages have preserved their traditional appearance almost unchanged since the Russian colonization of the White Sea coast. The village of Sosnovka, Murmansk Region. Photo: Gennady Aleksandrov.

Abandoned silver mine on Medwezhy (Bear) Island in the White Sea, Murmansk Region. Silver was mined here in the 17th-18th centuries, until 1740, when the onshore deposit became exhausted, and the vein had "gone to sea". Photo: Gennady Aleksandrov.

The next step in the colonisation of northwest Russia was led by the Slavs, primarily Novgorodians. In the early Middle Ages the territory of northeast Europe attracted people from neighboring regions, primarily for its valuable furs and ivory, the latter from walrus and mammoth fossils. Slavs and Scandinavians began to penetrate here no later than the 9th century. The Vikings, who sailed to the northern seas and entered the mainland from the north, were the first invaders. They met here with the Saami peoples (Lopars, as they were called in the ancient Russian chronicles). In the 10th -12th centuries, Vikings reached the lower stretches of the Northern Dvina River where they were stopped by the Novgorodians. Slavs arrived from the south in two independent waves. The Novgorodians came from the southwest. They started from Novgorod and Ladoga cities in large groups in boats and moved via rivers and lakes towards the White Sea. According to archeological records, they reached the White Sea shores by the 10th century. The oldest Slavic settlement, dating from the mid-10th century, has been found on the White Sea coast next to the mouth of the Onega River.

Besides Novgorodians, there were other Slavic invaders – peasants from eastern Russian principalities in search of new arable land and also to avoid the pressure caused by nomadic tribes from the southeast. They also migrated along the rivers, but from the opposite direction, namely from their sources downstream to their lower reaches. In the 12th century there were already numerous settlements established along the rivers Vaga and Northern Dvina by these Russian peasants.

The Pinega Portage has been known since the 12th century. The settlers dragged their boats across the isthmus from the River Pinega into the River Kuloi, sailing northwards into the Mezen Bay of the White Sea and hence to the mouth of the River Mezen. The modern city of Mezen now stands on the site of an old Kladnikova settlement. The most important routes of the Slavic colonization included the other major rivers, the Vaga, Northern Dvina and Onega. The city of Velsk was established in the upper reaches of the Vaga River. The settlement of Ust Vaga was built at the confluence of the Vaga and Northern Dvina. Two large settlements, Ust Pinega and Ivan Pogost were established in the lower reaches of the Northern Dvina. The Onega River had the city of Kargopol at the source and the city of Pogost-na-More at the mouth. The city of Ust-Yemetsk was established where a path from the Onega reached the Northern Dvina. The first stone castle in the north, called "Orlets", was built in 1342. Northern monasteries also played an important role in the formation of settlements. Colonisation of the Russian North by Orthodox monks started in the 12th century.

Suzdalians, from northeast of Moscow, moved north along the rivers Yug and Sukhona. Ustyug (nowadays the city of Veliky Ustyug) was their major settlement there. Nowadays, the local population is the result of the mixing of these migrations, with a predominance of Novgorodians. The most remote areas, situated in the northeast of the Arkhangelsk Region, e.g. Leshukonye (now Leshukonsk municipality), show the first traces of Russian colonisation dating to the 15th century and the first reliable information about a Slavic population of the middle and lower Mezen river wasn't recorded in the Russian census until 1623.

By the end of 15th century the process of initial colonisation of the territory of northwest Russia was completed. Most of the settlements which are known nowadays had been established and the boundaries of the areas populated by the various ethnic groups were defined. Northern peasantry was divided into two groups, the first being the Pomors, the inhabitants of sea-coastal areas. They were originally traders, and their main occupations were fishing and hunting sea mammals. Later they became skillful sailors. The second group comprised the "classic" Russian peasants, whose main occupation was agriculture. The limited area of land suitable for cultivation made them move towards intensive agricultural development.

Subsequently, the intensive colonisation of the Russian north by Russians has continued. For instance, in the Kola Peninsula, permanent settlements appeared at the mouths of the major rivers on southern and eastern coasts. The first records of Pomor villages on the Kola Peninsula, the Umba and Varzuga date from the middle of the 15th century, those of Kandalaksha, Kola, Kovda, Porya Guba, etc. from the 16th. There was also a system of temporary seasonal fishing encampments. This was reflected in traces of selective logging and fires along the coast. Forest at that time covered the whole Kola Peninsula and reached the very sea shore almost everywhere except for a narrow strip in the northeast. During the 16th century the system of Orthodox monasteries was founded. They developed their own livelihood and very quickly became the major economic centers.

The salt trade had a strong influence on the ecology of northwest Russia. The distribution of salt-works led to massive logging wherever timber transportation was possible, for instance in the valleys of rivers suitable for rafting and along the northern sea coast. To produce a pood (old Russian unit = 16 kg) of salt by extraction, about 1 m^3 of wood was necessary. The main centers of the salt trade in the north were situated along the northwest coast of the White Sea and Kola Bay. In the south they were concentrated along the Sukhona river (e.g. the cities of Totma and Ledengsk). Deforestation around the salt-pans led to their decline, the trade suffered due to shortage of wood, slowed down and then died. It seems apparent that the salt trade was the reason behind the first human-induced disappearance of pine forest along the northern rivers. In the north of the territory, reindeer husbandry (on a relatively small scale), intensive hunting and fishing were the main means of livelihood. Forest fires were frequent throughout the whole area in spite of minimal forest use.

Since the 17th century, the hold of the Russian state has strengthened. The pressure caused by the nomadic tribes from the southeast was no longer a major threat to the north. Feudal exploitation of the serfs and religious persecution of dissenters and Old Believers became the main reasons why people migrated to the north. In the course of the century, the salt trade gradually ceased there. Reindeer husbandry developed slowly: by the end of the 18th century there were only about 5,000 domestic animals. Then the process accelerated; by the early 20th century, the domestic reindeer population had reached 70,000 heads. The end of the 19th century saw the establishment of the first saw mills, the beginning of the industrial period. In the early 20th century, the forest industry started to play a major role in the use of natural resources in northwest Russia. Almost all the most valuable forests in the basins of the rivers Tuloma, Kolvitsa, Umba and Lake Imandra were felled. Many spruce forests, especially in the White Sea basin, owe their existence to selective logging for pine during the late 19th and early 20th centuries.

Thus, the human impact on forest ecosystems in the European part of the taiga zone of Russia has had a long tradition. This had already begun in the order of 5,000-10,000 years ago, first in the southern parts of the boreal forest zone, and then in the more northern areas. However, until the 20th century, the effect was not great. Anthropogenic transformation affected relatively small areas, whereas the process of spontaneous development of the taiga forests was dominant in the bulk of the territory. The only exception was forest fires. The frequency of naturally occurring forest fires has had a definite long-term pattern depending on the climate changes, but over the short-term the frequency often remains quite stable. Humans also affected the short-term frequency of forest fires, which increased significantly wherever human settlements appeared. Slash-and-burn cultivation was the main factor causing forest fires.

Selective cutting by the very small human population was a negligible factor in such extensive territories and did not lead to significant changes in natural forest structure. Even in the 17th century and later, when slash-and-burn cultivation accompanied by forest fires reached its peak phase, most of the territory of northwest Russia was still covered by intact forests.

Up till the 20th century, the territory of the taiga zone of European Russia belonged chiefly to the Arkhangelsk, Olonets, St. Petersburg and Vologda provinces, with a total area of about 125,000,000 hectares. Their area was almost identical in general outline to modern Murmansk and Arkhangelsk (without the Nenets Autonomous District), Leningrad and Vologda regions, the Republic of Karelia, and the Republic of Komi combined.

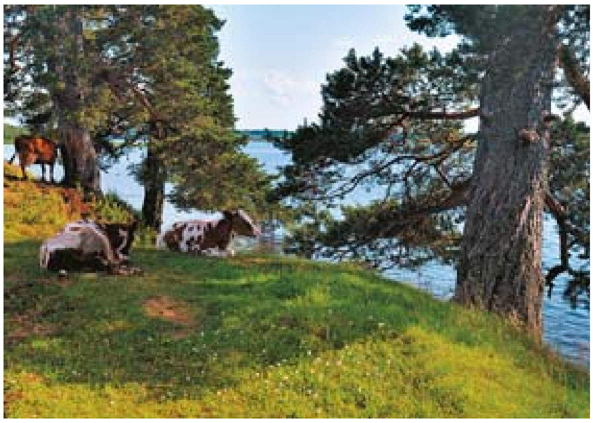
Agricultural activities. Slash-and-burn cultivation was the main type of agricultural activity in northwest Russia. Trees were felled and burned, and the land used for sowing crops over two or three seasons. After that the plow was abandoned and secondary forest took over. The area under permanent agriculture was relatively small. Almost all the land under cultivation was used for grain. Excellent meadows situated along the river valleys were suitable for cattle. The development of agricultural activities led to the gradual reduction of the forest-covered area. Forest was burned and also selectively cut. Documents of the General Land Survey and the Census of agricultural land indicate that in the 16th - 19th centuries, the proportion of arable land, hayfields and other categories of agricultural land was relatively stable, varying from 0.3-3.4% of the total area of northwest Russian territories. The only exception was the St. Petersburg province where, from the second half of the 18th century to the second half of the 19th century, the proportion of these lands increased significantly and reached more than a quarter of the whole area.

The Census of agricultural land conducted in 1887 incorporates significantly different figures on the proportion of agricultural land in the northwest Russian territories, especially in Olonets and St.

Petersburg provinces. These figures, however, did not fully reflect the actual situation, due to different approaches in accounting so-called "inconvenient" lands (e.g., water bodies, mires, etc.) which were excluded from the calculations because of their unsuitability for agriculture.

Slash-and-burn cultivation played a principal role in the anthropogenic transformation of intact forests because this was the only way to develop sustainable agriculture, which was the main means of livelihood for the population of the taiga territories. According to the legislation of those times, peasants who did not own land were allowed to practise slash-and-burn cultivation, but not closer than 3 miles from the villages. In the 19th century, burning of forest to obtain arable land was allowed only on earlier sites, i.e. in locations covered with young secondary forest, which indicated past agricultural use. Peasants needed a permission from the local forester for those activities. Burning of valuable timber forests was prohibited. However, in spite of these protective measures, slash-and-burn cultivation greatly affected adjacent forest through fires. According to eyewitnesses, out of 100 forest fires at least 90 originated from the burning of trees by peasants. The fires ended without any human involvement, due to natural causes, with lakes and rivers as fire boundaries, or after prolonged rains.

There are no original documents with statistics on the percentage of forest land treated by slash-and-burn cultivation in northwest Russia. For Finland, there are expert estimates (Heikinheimo 1915, Parviainen 1996) which show that more than 4,000,000 hectares of forest per year were subjected to slash-and-burn cultivation. In the early 20th century, about 50-75% of Finnish forests (including the southwestern part of the current territory of the Republic of Karelia), had been affected. Similarly, in the southern part of the Republic of Karelia, in the Arkhangelsk Region and in the northern parts of the Leningrad and Vologda Regions, the magnitude of this phenomenon was no less daunting. According to Valyaev (1984), the forest area involved in slash-and-burn in the modern territory of the Republic of Karelia was 10,000-15,000 hectares per year. Lyakhovich (1891) reported that in the Pudozh region of Olonets province the areas involved in slash-and-burn cultivation ranged from ca. 250-3,000 ha. The rotation period of slash-and-burn for a farm growing winter grains was, on average, 40 years, which meant that the areas involved in slash-and-burn cultivation constituted altogether 100,000 hectares (more than 15% of the forest covered land), of these ca. 60,000-80,000 hectares on the most fertile forest soils.



Valleys of large rivers were usually used first for agricultural production. Vologda Region. Photo: Elena Belozorova.

It is evident that over the ages, the total area under slash-and-burn cultivation in the southern boreal and hemiboreal sub-zones of European Russia amounted to many millions of hectares, usually on the most fertile forest sites. However, slash-and-burn cultivation did not affect all areas equally. For example, the middle boreal and northern boreal forest sub-zones were affected to a lesser degree due to adverse climatic and soil conditions. In the first quarter of the 20th century, this form of agriculture quickly decreased and finally completely disappeared.

The intensity of agricultural development of the territory was mainly determined by its landscape features. Only landscapes with more fertile soils, especially in lowlands covered with glaci-fluvial and lacustrine-glacial moraine deposits, were used for permanent agriculture. The Olonets lowland in the Republic of Karelia and the valleys of the major rivers such as the Northern Dvina, Onega and Sukhona, in Arkhangelsk and Olonets Regions, are examples of the oldest and largest centers of agriculture. Ridge-hilly moraine landscapes with sandy-loamy soils were also used for agriculture, whereas boggy soils and pure sandy soils were little used.

A similar situation can be noted at a sub-landscape level (ecosites of up to 1,000 ha and terrains of 1,000-10,000 ha). Even the areas generally considered as hardly suitable for the development of agriculture were used partially wherever soils were more fertile. For example in the middle-rocky terrain along the northern shore of Lake Ladoga all small-sized ecosites situated in depressions between ridges

Remains of old constructions found along small rivulets and streams that were flooded to float timber after opening the dam. River Porya, Murmansk Region. Photo: Gennady Aleksandrov.

(former lake bays) were transformed into farmland during the course of several centuries.

Forest management. National forest inventories were started for the first time in the Olonets province, in the first half of the 19th century. Later, the entire territory now comprising northwest Russia was included in the forest inventory. Regarding earlier times, data on the state of forest cover and its dynamics are available only from the materials on the distribution of the territory by land categories in the 18th -19th centuries.

Prior to the 20th century, the majority of boreal forests in European Russia have been subjected, in one way or another, to selective logging only. Clear cutting occurred only around steel mills, where timber was used for charcoal, and around sites of tar production. The industrial selective cutting was almost exclusively aimed at obtaining high-quality pine trunks. This is explained by the fact that spruce timber was not considered suitable for the wood industry (i.e. production of boards, planks, etc.) in foreign markets until the end of the 19th century. The ratio of pine to spruce logs sold at that time in northern European Russia was 3:1. Spruce logs began to be used due to the increasing exhaustion of available reserves of high-quality pine.

Generally forestry, according to contemporary definition, was conducted "by gut feeling" at that time (Gromtsev 2008). The most essential data, like forest management plans, forest productivity, accident rate in forest work, etc., were non-existent. The aim of the forest cutting was a large supply of wood for external and domestic markets rather than the use of timber products in the local economy. Timber floating was the only way of transporting the timber. A ramified hydrographic network consisting of numerous lakes, rivers and streams covered the whole territory. The spring water flows allowed the use of even small brooks for floating the timber which had been pre-harvested and stockpiled along the banks in winter. In fact, this was the system of transportation on millions of hectares of forest land. Using waterways, the timber was moved to the White Sea, lakes Ladoga and Onega, and then to the large industrial wood-consumers in Russia and abroad. Taking into account the poorly developed technical equipment of the time, the scale of timber production by selective logging was immense.

The forestry operations practiced in those times were not always in accordance with forest legislation. For instance, there are documents dated 1838 which report that in the Vologda and Olonets provinces unsustainable forest practices were common. Gromtsev (2008) cited the following: "Almost everywhere within 10 miles of the rivers Dvina, Sukhona and Yug, forest areas are devastated. Forest felling has been carried out using the same permit numerous times"; and "There is still forest in good condition, but only far from floating rivers; whereas forest along rivers and lake shores as well as next to sawmills has been spoiled to a great extent. Everybody cuts forest where it is closer and more convenient, or where the best trees can be found. In some regions forest is felled by the peasants of neighboring provinces. Rules about compulsory floating permits are not respected". The main impact was on pine- and larch- dominated forests. Timber companies tried to avoid felling spruce, and industrial logging in spruce-dominated forests began only in 1880.

In contrast to areas situated in hemiboreal and southern boreal forests, the areas in the middle boreal and northern boreal forest sub-zones remained almost untouched by forestry activities until the end of the 19th century. The reasons were the almost complete absence of roads and the extremely low density of the population. For example, the population density in the Kemi Uezd of the Arkhangelsk Province (present-day Kemi and Belomorsk municipalities of the Republic of Karelia) did not exceed 1 individual/km^2 even at the beginning of the 20th century (Pomor Encyclopedy 2001).

Before the 20th century, forest felling and harvesting were limited to areas where the features of the hydrographic network as part of the landscape structure made them possible. The more developed the lake-river system was, the more intense the logging activities (Gromtsev 2008).

Since the second quarter of the 20th century, clear-cutting as the basic activity of the forest industry has been extended into new territories. The volumes of timber harvested increased steadily (except for the war period 1941-1945) throughout the whole of northwest Russia. The peak of harvesting was during the 1960s –1980s period. Later, in the 1990s, a general economic crisis in Russia led to a steep decline in logging. In the mid-1990s, in the forest-rich regions of the central parts of European Russia (Arkhangelsk Region, the republics of Karelia and Komi), where a total annual allowable cut was about 53,000,000 m^3 of round timber, only 22,000,000 m^3 (41.5%) was, in fact, harvested. In these three regions, the volumes of timber obtained per 1 ha of forest land were 0.45, 0.30 and 0.60 m^3, respectively. Since the end of 20th century, the volume of timber production has gradually begun to grow (Gromtsev 2008).

Overall, from the 1930s, during a period of several decades, forests in northwestern Russia were subjected to severe human impact using clear-cutting on a great scale. The line of large-scale clear-cutting moved from south to north, together with other anthropogenic activities like development of the use of mineral resources (mining, trading), agriculture and construction of a road network. During the last 50 years, in the forest-rich boreal regions of European Russia (Arkhangelsk and Vologda regions, republics of Karelia and Komi), where the most intensive forest management regimes have been applied, clear-cutting of the forest has been carried out in an area of about 15,000,000 ha. (For comparison, the total forest-covered area in the Republic of Karelia is about 9,700,000 ha). Altogether, in all these regions, about 600,000,000 m^3 of timber were harvested during the second half of the 20th century. According to preliminary calculations, about 6,000,000 hectares of forest land were affected, i.e. about two thirds of the total forested area. As a result, by the beginning of the 21st century, large tracts of primeval forests remain only in less accessible areas (Nikonov et al. 2002).

Part of the peatlands in northwest Russia were intensively used as well. By the beginning of the new millennium, a total of 1,200,000 ha of peatlands had been drained in Arkhangelsk, Leningrad and Vologda regions, and the republics of Karelia and Komi (Gromtsev 2008, Forest Resources ... 2009). In Karelia, over 700,000 ha had been drained chiefly for forest growing on the drained lands, while in the Murmansk Region there was practically no drainage of peatlands at all. The main landscapes drained were paludified plains, especially the most extensive ones. Since the 1990s the drainage of mires and paludified forest lands for further forest growing has slowed and almost entirely stopped.

Thus, a great part of secondary forests that presently occupy the main part of the forest land in northwest Russia have been created under the influence of the following anthropogenic factors, different in their importance and scale: 1) concentrated final felling, widely used during the 1930s - 1960s with major effects on forest ecosystems; 2) wide- and narrow-strip clear felling (a present day method of timber harvesting); 3) slash-and-burn forest land treatment (widely used until the end of the 19th century) with associated wild fires; 4) selective and successive cutting of different intensities (ongoing during 18th–19th centuries); 5) drainage of mires and paludified forest lands for further forest growing, used very intensively during 1930s – 1960s, discontinued in the 1990s; 6) construction of infrastructure (roads, railways, power lines, pipelines, etc.); and 7) the tar trade and other factors (industrial pollution, etc.).

Nature use in 19th - 20th centuries included logging, mining, manufacturing and transportation, fisheries, whaling, agriculture and traditional crafts.

The inadequacy of the road network seriously hindered the development of northwest Russia until the late 19th and early 20th centuries, when railway construction and the use of the rivers and seas for transportation started to develop. This resulted in the establishment of numerous new settlements, not only along the waterways as had happened earlier, but chiefly in the watershed areas, formerly unpopulated. Traditional trade routes and market centers rapidly started losing importance. At the end of the 19th century the major railway Perm – Vyatka – Kotlas was built and became a primary means of transportation in the region. In 1894, construction of a narrow-gauge railway from Vologda to Arkhangelsk began, and in 1898, regular traffic on this branch-line was opened. World War I accelerated construction of the strategically important railway from St. Petersburg and Karelia to the Kola Peninsula. At the railhead, the mouth of the river Murman on the Barents Sea, the new city Romanov-on-Murman (later Murmansk, one of the largest polar cities) was founded. Construction of the railway was accompanied by clear felling along the line of construction, as well as the establishment of many small settlements. The frequency of forests fires along the railway rose very sharply, and has not decreased since.

In the first years of Soviet power (1918-early 1920s) the exportation of timber and wood materials via the White Sea ports increased dramatically due to very intensive logging and the processing of timber into boards. A trawler fleet was created in the city of Arkhangelsk. Socialist industrialization, in its first steps, resulted in the establishment of several new branches of industrial production, primarily giant lumber and wood processing plants (at Onega, Kotlas, and Arkhangelsk), shipyards (Severodvinsk), and construction of new railway lines (e.g. from Konosha to Velsk). During these years the traditional trade and settlement routes along the rivers Northern Dvina, Sukhona and Onega from north to south, from the White Sea coast to the central regions of Russia, were almost abandoned. Railways became the main routes, and the major industrial enterprises concentrated along the railway lines.
In the late 1920s to 1930s the next step in the development of northwest Russia began, and the anthropogenic stress on its natural ecosystems correspondingly increased. This resulted from the discovery of large deposits of apatite in the Khibiny Mountains by the geological expedition led by academician Aleksander Fersman (1883-1945) which in turn intensified geological studies in the Murmansk Region. Mining and mineral processing plants were built with their accompanying settlements: in the Khibiny area the railway station Apatity and the city of Kirovsk, and in the area of Monchetundra the city of Monchegorsk. The Nizhnetuloma hydropower station was built in the lower reach of the River Tuloma. Numerous logging companies were established in the south and west of Murmansk Region, in the territories of present-day Kandalaksha, Apatity, Kirov and part of Tersky municipalities. The communities of the local Saami people were transformed into Soviet reindeer farms.

In 1939, railway construction began between the cities of Konosha and Vorkuta, crossing the whole Arkhangelsk Region and the Republic of Komi from southwest to northeast. This line was commissioned in December 1941. The city of Velsk, a major center of the timber processing and tar trades, developed from an old Russian settlement situated at the intersection of this new railway line (a branch from Konosha to Kotlas) and the old road from Arkhangelsk to Vologda. The city Nyandoma was established near the east-west branch of the railway. Prior to World War II, a new pulp and paper mill was built in the village of Koryazhma (thus transformed into a city), next to the old city of Kotlas; together they formed the Kotlas industrial and transportation center. At the same time, the westernmost part of northwest Russia was developing differently. Within this western strip there were differences both between the southern and northern parts, as well as between the territories belonging to Finland (prior to 1940) and the Soviet Union. In the south of Murmansk Region (villages Alakurtti, Kairala, etc.) there was arable farming combined with cattle-raising, whereas in central and northern areas of Murmansk Region, only reindeer husbandry was practised. These areas were characterized by frequent forest fires.

During World War II, forest fires were the main human influence on natural ecosystems in northwest Russia. Active combat operations including bombing by aircraft took place in the areas of Salla-Kandalaksha and Pechenga-Murmansk. There was

The nature of Murmansk Region suffered chiefly through the development of the mining complex. Gigantic quarries of apatite, copper-nickel ores, iron ore and their surrounding waste piles completely destroyed extensive natural areas. A quarry in the Kovdor iron-ore deposits, Murmansk Region. Photo: Grigory Ivanyuk.

trench warfare in these and other areas adjacent to the Finnish-Russian border, resulting in numerous burnt forest areas of different sizes eastwards to the valleys of the West Litsa and Wehrmann Rivers. There were also larger forest fires in the area of Mustatunturi, the scene of intensive fighting for the possession of the Rybachy and Middle peninsulas.

After World War II, large-scale development of the region continued in several ways. The main emphasis was on traditional farming and timber production for export. Pulp mills in Voloshka, Kodinsk and Pustozersk, the paper mill and the Lenin' sawmill (also called "the third sawmill") in the city of Arkhangelsk, and the Solombala sulphate pulp mill were considerably strengthened and extended. In 1961, the first stage of the Kotlas pulp and paper mill, the Maymaksan sawmill and the Maymaksan wood-processing plant were put into operation. Large shipyards for both ships and submarines were constructed in the city of Severodvinsk. A spaceport, "Peaceful", and a missile test site were built at Nenoksa. In the 1960s-1970s, geological exploration increased and several new deposits of oil, gas, ore, bauxite, diamonds, etc., were discovered. Exploitation of most of them was quickly put into operation, e.g. iron ore deposits (in Olenegorsk and Kovdor), copper-nickel ores (in Monchegorsk and Pechenga), mica (in Rikolatva), and rare earth-metals (in Revda). Production of apatite concentrate (in Apatity) was increased, and the metallurgical combines in the cities of Nikel, Monchegorsk, Zapolarny and Kandalaksha started production. Housing construction and improvement of public services were started in the cities and villages.

A modern transportation network was created, including railway lines to Kovdor and Pechenga-Nickel, from the main line to Murmansk. The Leningrad-Murmansk highway was completed. Design work was started for the step-by-step construction of hydroelectric power stations along almost all the major rivers of the Murmansk Region. In 1968, a pilot tidal power station was put into operation in the Kislaya Bay of the Barents Sea. In 1973, the Kola nuclear power station was put into operation.

Forest logging activities were spread throughout the whole of northwest Russia. The volume of timber production was determined only by the technical capabilities of the timber companies (lespromphozes). During the 1950s–1980s almost all of the available forests of high quality timber were threatened by logging.

In the post-Soviet period, after the collapse of the Soviet Union, economic development was concentrated only in the most populated areas (Leningrad, Arkhangelsk and Kotlas agglomerations), and in the biggest cities (St. Petersburg, Petrozavodsk, Cherepovets, Vologda, Murmansk, Mirnyi, Onega and Velsk). Most of these areas and cities are located on the banks of the rivers Northern Dvina, Vaga, Vychegda, Onega, Pinega, Mezen, and along the railways Konosha–Arkhangelsk, Vorkuta– Konosha, and Obozerskaya–Murmansk.

1.2.2. Structure of modern nature management

Over the past 10 years, the total area of agricultural land within the Gap-study area has been significantly reduced (in different proportions depending on the region), with a corresponding increase in forest land, which has gradually been taking over

Sulphur dioxide emissions from the copper-nickel plants in the cities of Monchegorsk and Nikel in the Murmansk Region have led to the formation of man-made wastelands. Photo: Konstantin Kobyakov.

In many areas close to human settlements, forest fires occur so frequently that regeneration is restricted. In the north of the study area, this leads firstly to extremely low-density forest, and then to complete deforestation. Photo: Konstantin Kobyakov.

abandoned agricultural land. Generally, the area of forest covered land, protected areas and land occupied by settlements has been increasing almost everywhere.

It is obvious that former agricultural land which has fallen into disuse is invaded by trees and thus transformed into the category of forest covered land, though a fraction of former agricultural land is now included in protected areas. At present, the total area of abandoned agricultural land in the boreal forest zone is more than double the area of land still in agricultural use. In those regions where agricultural land constitutes a large proportion of the total area (Leningrad and Vologda Regions), the decrease in agricultural land was, on average, 10%. In other regions, e.g. in the Republic of Karelia, the reduction of agricultural land was even more pronounced, but as the original total area under agriculture there was small relative to forest land, the effect on the overall picture is almost negligible. During this same ten-year period, some of the over-moist areas formerly categorized as forest covered land have been moved to the water fund category as mires.

In the **Arkhangelsk Region** (State report of the Arkhangelsk Region…2010), the main types of nature use are logging, fishing, mining, agriculture, and hunting. The total forest area is 28.5 million hectares (= **mha** hereafter). The area of the exploitable forests is 19.8 mha, or 69% in relation to the total forest area (including 19.7 mha administered by the Arkhangelsk Region). Forests where felling is restricted (within protected areas, protected forests, etc.) occupy 9.4 mha (including 8.8 mha administered by the Arkhangelsk Region), or 31%. The total standing volume of major forest tree species within the exploitable forest areas administered by the Arkhangelsk Region constitutes 2.6 billion m^3. Of these, the average standing volume of mature and over-mature trees in coniferous forests is 142.6 m3 per hectare; in deciduous forests this figure is 185.6 m^3. The final yield in 2009 was calculated at 21.8 million m^3 (= **mm³** hereafter), including 13.9 mm^3 in coniferous forests (http://www.dvinaland.ru/economy/timber/2009.php, data on 01.01.2010).

The forest sector, primarily logging and timber transport, has been a key sector of production in the Arkhangelsk Region for the last 300 years. Over the past 100 years, the annual cutting volumes have averaged 10-15 mm^3 of timber. In the 1970s and 1980s, the volume of the annual timber harvest reached 25 mm^3. In the 1990s and the first decade of the new millennium, the volume decreased significantly. At present, the annual timber harvest varies considerably from year to year depending on the demand for timber, the general economic situation and weather conditions. For instance, in 2008, the total was 10.3 mm^3 (of these, 8.3 mm^3 in coniferous forests) or 47% of the allowable cutting volume. In 2009, the total was 10.9 million m^3. The annual cuttings use only about 50% of the allowed cutting area, so the forest industry could expand significantly. In 2008, logging affected a total of 100,800 ha compared with 93,500 ha in 2009 (Forest Management Plan ... 2008a).

The bulk of logging is carried out as clear-cutting in mature and over-mature stands. In 2006-2009, on average 62-87% of timber was harvested by clear-cutting. Sanitary felling produced about 12-15% of the wood harvested annually. In the period 1999-2009, the clear-cut area ranged from 40,000 hectares in 1999 to 54,500 ha in 2008.

Logging, Arkhangelsk Region. Photo: Artyom Stolpovsky.

Logging, Republic of Karelia. Photo: Sini Eräjää.

Currently, the share of the forestry sector is 11% of the total industrial output of the Arkhangelsk Region. The sector operates 211 plants and factories, including three large pulp and paper mills. In total, 425 forest plots with a total annual volume for harvesting of 15.0 mm^3 are held under long-term leases for wood, pulp and paper production. Besides timber harvesting, a certain amount of forest in the Arkhangelsk Region is dedicated to other purposes than wood production. Many forest plots are currently held under long-term leases for such uses as harvesting forest berries and mushrooms, production of birch sap, for hunting, game management, recreational use, etc.

In total, 34,300 ha of pine-dominated forests are suitable for industrial resin extraction. However, the actual volume of resin production is rather low, e.g. in 2007 only 365 ha of pine forest were utilized for resin extraction. Two plots with a total area of 296 hectares are held under long-term leases for this purpose.

Annual yield of wild forest berries reach 26,600 tons, and of mushrooms 5,100 tons in the three main species groups: *Boletus, Leccinum* and *Lactarius*. Average yield of birch sap collected annually may exceed 500,000 tons. Mushrooms and berries are harvested by local people for their own use, as well as for sale. Two forest plots with a total area of 12,087 ha are held under long-term leases for the gathering of non-timber forest resources, with an estimated harvest of 11.2 tons of mushrooms and berries annually. There are four major companies buying forest mushrooms and berries every year in the Arkhangelsk Region. However, yields of forest berries and mushrooms compared with timber harvesting are very low. According to estimates, only about 20% of the total crop of forest berries is harvested and about 50% of mushrooms.

The total area of forest in the Arkhangelsk Region utilized for reindeer husbandry is 201,100 ha. There are 30 forest plots totaling 75,000 ha used for recreation; 12 plots and 155,200 ha for research and educational activities; 107 forest plots totaling 3,483 ha for geological exploration of mineral resources and mining of mineral deposits; 2 forest plots totaling 2 ha for the construction and operation of reservoirs and other artificial water bodies; 88 forest plots totaling 2,310 ha for the construction, reconstruction and operation of electric power lines, communication lines, roads, pipelines, etc; and 4 forest plots totaling 14 ha for wood processing and treatment of non-timber forest resources.

Game animals, hunting. The most important wild animals and birds exploited by hunters in the Arkhangelsk Region are elk (*Alces alces*), wild reindeer (*Rangifer tarandus*), brown bear (*Ursus arctos*), squirrel (*Sciurus vulgaris*), mountain hare (*Lepus timidus*), marten (*Martes martes*), fox (*Vulpes vulpes*), beavers (*Castor fiber* and *Castor canadiensis*), otter (*Lutra lutra*), capercaillie (*Tetrao urogallus*), black grouse (*Tetrao tetrix*), hazel grouse (*Bonasa bonasia*), willow grouse (*Lagopus lagopus*), geese and ducks. The populations and the annual catch of different species vary greatly from year to year. On average, over 160 tons of meat is produced annually in the Arkhangelsk Region through hunting. Amateur and sport hunting are more common than commercial hunting. Elk and reindeer hunting constitute an essential part of the social life of rural villagers. The area reserved by the Arkhangelsk Region for hunting is 27.3 mha. In 2009, the total area of forests under long-term use for hunting was 24 plots totaling 1.8 mha.

Logging, Murmansk Region. Photo: Konstantin Kobyakov.

Transportation of illegally harvested timber from the reserve "Shilovsky", Arkhangelsk Region. Photo: Artyom Stolpovsky.

Mining and quarrying. Over the past 75 years, about 1,500 mineral deposits have been discovered and explored in the Arkhangelsk Region, among them bauxite, diamonds, oil, gas, carbonate raw materials for pulp and paper mills, cement, gypsum, and building stone including basalt, granites and gneisses, sand, gravel, brick clay, etc. In addition there is underground fresh and mineral water. Altogether, 4 large and 95 small companies are currently operating in the fields of mining and refining of mineral deposits in Arkhangelsk Region, with a further 13 companies extracting mineral water.

Several mineral deposits are considered to be of federal significance, e.g. the North Onega bauxite area in Plesetsk municipality, one of the largest alumina mines in Russia and in the former Soviet Union; two deposits of diamonds called Lomonosov and Grib, after famous Russians; the western part of the "Belovodskoye" deposit, belonging to the "Iksinsky" bauxite deposit group; the eastern section of the "Shvakinskoye" limestone deposit; "Savinskoye" limestone deposit and the "Sheleka" site of the "Savinskoye" clay deposit; and the "Glubokoye" gypsum deposits in Kholmogory municipality.

In addition, the Arkhangelsk Region has significant reserves of peat; there are 627 sites exceeding 10 ha with commercial reserves totaling 718 million tons of peat, of which only 47,000 tons are currently extracted annually.

Water use. Generally, Arkhangelsk Region has large resources of surface water available. Water bodies are represented by a dense network of rivers, streams and lakes. Their total surface area is 811,500 ha, of which 110,400 ha are considered part of the state water fund. Underground drinking water supplies estimated at 1,328,340 m^3/day are available from 27 sources; 8 deposits of mineral water reserves of 21,476 thousand m^3/day from 8 sources; and industrial water, with iodine and sodium chloride, from 3 sources. Most of the groundwater reserves are concentrated in the Plesetsk municipality (54% of the total amount in the Arkhangelsk Region), and in the Primorsky municipality (36%).

The rivers of the Arkhangelsk Region are mainly used for navigation and for timber floating. There is regular shipping on the biggest rivers, like the Onega, Northern Dvina, Vychegda, Emtsa, and Mezen. Of these only two, the Northern Dvina and the Vychegda, have navigation over an extended length throughout the year. The total length of navigable waterways in the basin of the Northern Dvina is more than 5,500 km. On other rivers navigation is possible only on stretches with highest water flow, from a few tens of kilometers on the Emtsa to 100-200 km on the Onega, Vaga, and Mezen. The Onega has numerous rapids so shipping is not possible along the whole river but only on two isolated stretches, between the villages Porog - Turchasovo, and between the last rapids and the city of Onega, which is situated at the river mouth, in the Onega Bay on the shores of the White Sea. Shipping is possible for the period from May to October. The annual volume of the cargoes constitutes about 2 million tons, about a quarter of which is made up of timber rafts. Annual passenger traffic is estimated as about 1 million people, mostly on local lines. The Northern Dvina and its tributaries account for the bulk of this passenger and freight traffic.

There is seasonal shipping only during the spring flood on many smaller rivers, e.g. the Vym, Ustya, Pinega, Kuloi, Vashka, etc., as well as in the upper reaches of the bigger rivers like the Vychegda, Vaga, and Mezen. The length of this shipping season depends on water flow, varying between one or two weeks to perhaps two months or more. The cargo totals involved do not exceed one million tons per year, mostly as imports from - rather than exports to - other regions; incoming cargoes are 3-5 times greater than exports, on average; on the Pinega River 8-10 times greater.

Timber rafting using tugboats is performed on all the big rivers located within the taiga zone during the whole navigation season. The rafts are delivered to the cities of Onega, Arkhangelsk, and Kamenka, where most of the mills and wood processing enterprises are situated.

Little use is made of hydropower resources; water mills, which were in common use just 40-50 years ago, are currently not exploited.

Production of fish and seafood. 20% of the total fish catch of the northern basin of European Russia and most of the production of such bio-resources as edible seaweed and marine animals are concentrated in the Arkhangelsk Region. The fishery resources of the region include the White Sea, more than 22,000 lakes, and rivers with a total length of more than 90,000 km, including 20,000 km used by spawning salmon, which are under a special protection regime. The main commercial fishing rivers are the Northern Dvina, Vaga, Viledi, Pinega, Vychegda, Ustya, Veli, and Mezen. According to the data of

01.01.2009 (http://www.dvinaland.ru/economy/fish/), there were 239 small enterprises and over 50 relatively large fishing companies specialized in fish trade (37 companies), fish processing (4 companies) factories and trading and processing of seaweed (2 companies). The most important commercial sea fish species are cod *(Gadus morhua)*, the White Sea herring *(Clupea pallasi marisalbi)*, haddock *(Melanogrammus aeglefinnus)*, flounder *(Pleuronectes platessa)*, catfish *(Anarchichas lupusmaris-albi)*; the anadromous and semi-anadromous fish and lamprey species such as Atlantic salmon *(Salmo salar)*, pink salmon *(Oncorhynchus gorbuscha)*, whitefish *(Coregonus lavaretus)*, European cisco *(Coregonus albula)*, river lamprey *(Lampetra fluviatilis)*; and those of the river and lake fish species: sturgeon *(Acipenser sturio)*, pikeperch *(Stizostedion lucioperca)*, roach *(Rutilus rutilus)*, grayling *(Thymallus thymallus)*, perch *(Perca fluviatilis)*, pike *(Esox lucius)*, burbot (*Lota lota)*, and ide *(Leuciscus idus)*.

Agricultural production. Agriculture in the Arkhangelsk Region is relatively poorly developed due to the limited amount of suitable arable land, located mainly in the southern areas of the region, and low soil fertility. Generally, agriculture is focused on cattle farming for meat and milk, and on the growing vegetables. Few other agricultural products are produced in the area so they are supplied by other regions. In total, there are 240 agricultural and processing enterprises, 100 large farms and 13,500 small subsistence farms. The total area of land suitable for agricultural is 630,000 ha. Of these, 280,000 ha are arable land, hayfields, pastures, etc. The area of drained land is 81,000 ha, of which 29,500 ha are currently in poor condition with the drainage network in need of repair. In 2008 only 27,100 ha were sowed with seed.

Vologda Region (State report …2010b). According to the Census of State Land (01.01.2009), the total area of the Vologda Region was 14.5 mha, including 4.5 mha of agricultural land, 198,300 ha under settlements, 131,600 ha dedicated to industry and other special purposes, 139,000 ha in protected areas, 8.6 mha of forest resources, and 841,500 hectares of reserve lands. Thus, the area of forest resources predominates, covering 59.7% of Vologda Region. Agricultural land covers 31.2%, reserve lands 5.8%, and all other land categories together 3.3%.

Industry. Nearly 300 large and medium-sized enterprises and about 550 small businesses form the backbone of industry in Vologda Region. Rated by the total of industrial production per capita, Vologda ranks third among provinces of the Northwest District of Russia, and tenth in the whole Russian Federation. The sales volume per capita of this output is almost 1.4 times higher than the national average. Processing of natural resources and production of basic metals are the two largest industrial branches. According to government statistics of industrial output, these two branches, together with production and distribution of electricity, gas and water, constitute 53.2% of the gross regional product. A break-down into more detail shows the following shares of the gross regional product: metallurgical industry (50.6%); chemical production (13,7%); wood processing (3%); machinery and equipment (4,7%); manufacturing of food products (8,9%); textile and textile products (3%); glass production (1,3%); production and distribution of electricity, gas and water (8,9%); pulp and paper industry (0,5%).

Water supply. Total water consumption of the Vologda Region is around 600-650 mm^3 a year, as follows: industrial use (80%); drinking water (16%); agricultural use (about 4%). The main source of water for cities and other settlements is surface water, i.e. the water contained in water bodies, which provides about 85% of the water for drinking and for industrial use. There are 158 water intakes, with 53 of these providing drinking water, the other 105 water for technical purposes of the various companies and organizations. 15% of the drinking water supply is provided by 2,671 artesian wells.

The total length of water supply networks in the Vologda Region exceeds 4,300 km. All cities and most rural settlements, with the exception of a few remote small villages, have piped water supplies.

The total length of sewage pipes in the Vologda Region is over 2,000 km. Sewage is treated at 420 facilities, which process over 122 mm^3 annually or 94.7% of the annual amount of water coming from sewage. The largest sewage treatment plants are located in the city of Sokol, situated on the Sukhona River 35 km north of Vologda. The city of Cherepovets, where the biggest metallurgical plants in the Vologda Region are situated, possesses the largest treatment facilities for water taken into water supply networks. At present they are considered the most modern in the whole of northwest Russia.

Transportation. Currently there are 567 bus routes with a total length of 25,600 km; 8 routes of urban electric transport with a total length of 75 km; 768 km of railways for public use; and 1,577 km of inland waterways used by waterborne traffic. In addition, scheduled civil airline routes cover altogether more than 1,500 km in Vologda Region. The primary means of passenger transport are cars and urban electric railways, which account for about 96.9% of all passenger traffic. Railways are of primary importance in cargo transportation. In 2009, the total volume of passenger traffic was 155 million people.

One of the gas pipeline networks supplying northwest Russia and European countries runs through Vologda Region. Each year, about 84 billion cubic meters of natural gas are pumped through two systems, i.e. Ukhta – Torzhok and Punga – Vuktyl – Ukhta – Gryazovets. Only about 10% of this volume is consumed within the region. The gas passing through Vologda Region originates from areas to the east, namely from northern regions of the Tyumen Region and from the "Vuktyl" gas deposit in the Komi Republic.

Vologda Region is crisscrossed by a total of almost 4,000 km of gas pipelines, both main lines and laterals, and by 37 outlet pipelines with total length of approx. 560 km. There are 5 compressor stations in operation (January 1, 2010). The main natural gas pipelines are: Ukhta – Torzhok I, II, III; Ukhta – Torzhok IV (Urengoy – Gryazovets); Northern Tyumen region – Torzhok; Gryazovets – Leningrad I, II; Gorky – Rybinsk – Cherepovets, and the Gryazovets ring pipeline – Moscow Region. For exporting Russian gas to Europe, the ongoing project "North European Gas Pipeline", aimed at linking Russian gas sources directly with the European gas network, is under construction in the Vologda Region. The "Pochinki-Gryazovets" section of pipeline in Gryazovets is intended to feed natural gas from the central to the northern transmission corridor. Recently a lateral pipeline and inter-settlement network has come into operation in the Verhovazhye municipal area, supplying consumers in the remote settlement of Verhovazhye. A proposed new pipeline system from the gas deposits of the Yamal Peninsula will further increase capacity. This new pipeline will be situated in the same technological corridor with the existing gas transportation system of Vologda Region. Currently, preparation work for the construction of the first part of this pipeline is in progress.

Republic of Karelia (State report …2008, 2009). According to the Census of State Land (01.01.2008), the total area of the Republic of Karelia was 18 mha, including 2.66 mha of water and 210,300 ha of agricultural land, this latter figure including 104,300 ha for land redistribution. Further, 75,200 ha are devoted to settlements; 154,200 ha to industry and other special purposes; 292,800 ha to protected areas; and 123,600 ha to reserve lands.

The total area of forest resources (so called state forest fund, which incorporates also small parts of the largest water bodies) is 14.8 mha. Of these, forest covered land occupies 9.4 mha, or 62.8% of the total forest fund area. The total stock of growing timber is 967 mm^3, of which mature and overmature stands account for 437 mm^3, with 380 mm^3 of this figure as conifers.

The final yield in 2007 was calculated at 8.8 mm^3, and the figure for the total amount of the allowed timber trade was 7.8 mm^3, or 89% of total of the possible cutting volume. The real annual felling in 2007 was 6.9 mm^3, of this 5.6 mm^3, by the main lease-holders. The volume of timber transported from forest to consumers was, in fact, 6.5 mm^3. During recent years, the annual cuttings have been more or less stable, comprising about 62–64% of the allowable cutting area. Poor development of the road network is the main obstacle to further expansion of the forest industry.

According to data of 01.01.2008, there were 154 long-term leases of forest areas to 62 users on the territory of the Republic of Karelia. Competitive leasing covers 94% of the total leased forests. The total area of forest land leased for timber production is 10.9 mha, with over 7 mm^3 of timber (i.e. 80% of the total annual amount of wood growing stock). In addition to long-term leases, timber has also been sold through auctions. For instance, in 2007, altogether 35 auctions to sell standing timber totaling 162,600 m^3 were conducted in the Republic of Karelia. Although officially there is strict control and supervision of logging to reduce forest violations, illegal logging is still the main current problem in the Republic of Karelia.

Reforestation is one of the most important tasks of the forest industry in the Republic of Karelia. In 2007, work was carried out on 26,600 ha, including forest planting over an area of 6,500 ha. Forest nurseries produce about 30 million seedlings annually for replanting cut areas.

The Republic of Karelia has vast mineral resources and significant potential for development. For instance, there are large reserves of ferrous, nonferrous and rare metals, including gold and platinum, as well as non-metallic minerals and energy resources. In recent years, the mining complex has become one of the most promising sectors for the development of the economy. Mineral resources include 829 explored deposits, which incorporate 27 types of minerals. There are huge stone reserves exceeding 1,700 mm^3 for crushed stone production and 4.6 mm^3 for stone blocks, while the reserves of sand and sand-gravel material amount to over 37 mm^3. In total, 40 deposits of crushed stone, 10 deposits of building stone, and 10 deposits of sand and sand-gravel have been developed.

The Lukkuluysvaara and Kamennoozerskaya areas, as well as the subsurface areas called "Lobash 1", "Mayskoye", "Tsypringa" and others have been searched for precious metals. JSC (Joint Stock Company) "Alrosa" is conducting geological searches for diamonds throughout northwest Russia. The company "Ashton Mining Limited" continues the search for diamonds in the Zaonezhye Peninsula. The "Nafta Nickel" company has received four licenses covering searches for and extraction of nickel and one license for exploration and production of molybdenum. In 2007, a license was granted for geological investigations near the settlement of Ladva relating to explorations for hydrocarbons. 97 licenses for exploration and production of common minerals and 36 licenses for rare minerals have been approved during 2002- 2007.

Water Resources. The volume of water in Karelian reservoirs is 80.2 km^3, of which the total usable capacity is 18.6 km^3. 47% of annual river flow can be regulated. There are 65 km^3 of water in lakes that have retained their natural state. In addition, there are large volumes of water in Lakes Onega (including the Upper Swir reservoir) and Ladoga. Most of these water resources (78%) lie in the White Sea basin, mainly in artificial reservoirs. About 63% of the total river flow in the White Sea basin is regulated, and about 90% of the total usable water capacity of reservoirs is situated in the White Sea basin.

Within Karelia, 14 reserves of underground water have been found. Proven reserves for drinking and technical water supply constitute 36,100 m^3 per day, including those for industrial development estimated at 22,700 m^3 per day. The share of groundwater is about 1% of total water procurement, and 3% of domestic water supply.

Resources of fresh groundwater in the Republic are estimated as 814,700 m^3 per day. The most important users are industrial enterprises, with consumption of more than half the water intake and producing more than half of waste water. The other major consumers are housing and communal services. In comparison, agriculture, transport and others users consume relatively small amounts. In 2006, total water intake from natural sources amounted to about 245 mm^3, including those from the surface water bodies (242 mm^3) and groundwater (2.5 mm^3). The volume of waste water discharged into surface water bodies amounted to 243 mm^3. Water recycling systems handled annualy over 1,000 mm^3.

In 2006, 95 plants for waste water treatment, with a total capacity of 335 mm^3, were in operation in the Republic of Karelia. More are required, as sewage treatment facilities are totally absent in the four cities of Kemi, Belomorsk, Medvezhyegorsk and Pudozh, and in two large villages, Loukhi and Kalevala (all centers of their respective municipalities); waste water is discharged directly into water bodies which, as a rule, are also the source of water supply for these settlements.

Pollution. Emissions of various pollutants into the air were 126,600 tons, with 26,500 tons of solid pollutants, and 100,000 tons in gaseous form. The main pollutants are: sulfur dioxide, carbon monoxide and oxides of nitrogen. The main sources of air pollution in Karelia are pulp and paper mills, metallurgical plants, the mining industry and the energy sector. The average amount of emissions is 0.81 tons/ km^2. The greatest amounts (in all, 80% of the annual total for the Republic) were registered in the biggest industrial centers: the cities of Kostomuksha (47,900 tons), Kondopoga (18,400 tons), Segezha (16,400 tons), Nadvoitsy (6,500 tons), Pitkyaranta (6,300 tons), and Petrozavodsk (5,200 tons). In recent years, a reduction of harmful emissions has been noted in many areas, like Kalevala, Kemi, Kondopoga, Pitkyaranta, Pryazha, Pudozh, and Suojärvi municipalities, and also in the cities of Petrozavodsk and Sortavala. A total of 1,678 gas purification stations and particle collection systems neutralizing around 150,000 tons annually (i.e. more than 55% total pollutants) are currently operating in the Republic of Karelia.

Cumulative industrial production of waste material amounts to over 100 million tons; of these, 99.7 million tons (98%) are considered waste of hazard category 5 (i.e. in practice, not dangerous), most of which result from mining operations. Compared with the previous year 2005, the volume of waste has grown by 0.2 million tons. Wastes of hazard categories 1-4 constituted 2 million tons (2.0% of annual total). Of these, only 50.9 tons are assessed as hazard category 1. Wastes of hazard categories 1 and 2 were treated to neutralize their harmful effect, with 91% of category 1 and 92% of category 2 being rendered harmless. Waste from grades 3 and 4 were decontaminated by 87% and 85% respectively, and then used. Recycling of wastes of hazard category 5 was only 9%. Each year, all solid wastes are placed in landfills.

Leningrad Region. The population of the Leningrad Region on June 1, 2008 was 1,631,700, with 1,083,300 (66.4%) in cities and 548,400 (33, 6%) in rural areas. The total number of settlements was 2,945 (31 cities, 32 townships and 2,882 villages).

Transport infrastructure. The length of railways is more than 3,000 km, of which 30% are electrified. The density of the railway network is 32 km per 1,000 km2. The throughput of cargo is more than 100 million tons per year. There are more than 13,000 km of roads, the density of the road network being 108 km per 1,000 km2. The construction of a ring road around the city of St. Petersburg is in progress. The length of the navigable waterways is almost 2,000 km. The river ports are Leningrad, which is equipped with modern facilities for processing and transport of goods, and Podporozhye; the seaports are in Primorsk, Vysotsk, Ust-Luga, and Vyborg. "The Northwest River Shipping Company" carries more than 40 million tons of cargo annually on the waterways of the Leningrad Region.

Industrial capacity: The industrial complex of Leningrad Region is represented by three main activities: mining, manufacturing, production and distribution of electricity, gas and water.

Mining and quarrying. Leningrad Region has abundant mineral resources: bauxite, clay, phosphate rock, shale, granite, limestone and sand, making up a total of 2.2% of the industrial output. The main products include natural building materials such as ceramic and refractory clays, limestone, dolomite, crushed stone, sand, and gravel. The largest enterprises in this sector are the JSC (Joint Stock Company) "Granit-Kuznechnoye", JSC "Kamennogorsk Quarry", JSC "Kamennogorsk non-metallic materials", JSC "Vyborg Quarry", JSC "Pogranskoye union mines", and JSC "Leningradslanets". Mining employs 6,800 people in Leningrad Region.

Manufacturing plays a primary industrial role and makes up 81.6% of the gross regional product. The average number of employees in the manufacturing sector is 121,900. This sector includes a variety of activities, with the manufacture of food products, beverages and tobacco covering 29.1% of the annual production of the processing industry. There are also meat-packing plants, dairies, feed and canning factories, which produce a wide range of goods. The manufacture of transport equipment (13,1%), pulp and paper production including publishing and printing activities (12.1%), coke and petroleum products (11.5%), non-metallic mineral products (9.5%), chemical industry (8%), basic metals and fabricated metal products (4.5%), machinery and equipment (3.6%) are other major contributors to the gross regional product.

Production and distribution of electricity, gas and water constitute 16.2% of gross regional product of the Leningrad Region, with 30,500 employees on average.

Agriculture. Agricultural enterprises are responsible for 60.7% of annual agricultural production in the Leningrad Region, with production by local people for their own use in second place, local production for sale in third place. A cattle farming is the most important branch of agriculture.

Murmansk Region. The formation of a large industrial complex and the economic development of nature use is the result of Murmansk Region's position in relative proximity to the industrialized regions of Russia and the existence of the Northern Sea Route with year-round navigation in combination with its rich resources of minerals and fisheries.

The city of Murmansk with its surrounding settlements, including Kola village, form the industrial and transport center. Murmansk harbor is the largest ice-free port in northern Russia. Fishing and fish processing are the main branches of industry. Along with fishing, many other industries are concentrated there. The second industrial hub is situated in the city of Kandalaksha, on the shore of the Kandalaksha Bay of the White Sea. It includes a seaport, a major railway station of the October Railway (Moscow – Murmansk) and the Kandalaksha aluminum plant, which uses imported raw materials and hydroelectric power from the river Niva.

The primary employers of the urban areas in Murmansk Region, as for practically all the cities excluding Murmansk, the capital, are formed around mining and processing enterprises. For example the cities of Monchegorsk and Zapolyarny have mining, ore-processing and metallurgical plants; the city of Nickel has JSC (Joint Stock Company) "Norilsk Nickel"; the city of Olenegorsk has the iron ore-processing plant of JSC "Alcon"; Kirovsk and Apatity have the mining and chemical plants of JSC "Apatite"; Kovdor has the iron ore-processing plant of JSC "Kovdor GOK" and factories for processing and enriching owned by JSC "Kovdorslyuda"; and so on. 70 deposits producing 29 kinds of minerals are currently being operated. Intensive mining leads to considerable violation of the landscape, with the formation of pits and dumps. Ore quarries occupy extensive areas; the larger ones can be more than 300m deep. Ore processing plants also produce vast waste dumps.

Murmansk Region has one nuclear power station, 17 hydro power stations and 3 thermal power stations. Construction of the hydropower stations led to the creation of a number of artificial reservoirs and caused extensive flooding, producing large dead forest areas as well as eliminating many salmon spawning grounds. Discharges of warm water by the Kola nuclear power plant into Lake Imandra have caused alterations in the aquatic ecosystems in White Bay of the White Sea.
Timber industry is at a fairly low level in the economic life of Murmansk Region, forming only 0.3% of the gross regional product. The total volume of timber harvested in 2007 was 148,300 m^3.

Reindeer husbandry is a typical zonal type of nature use in the area, which lies entirely in tundra, forest-tundra and northern boreal forest sub-zones. The reindeer population is kept within the limits 70,000-80,000 animals to avoid overburdening the grazing areas. Grazing of the reindeer has a significant effect on tundra and forest ecosystems due to the slow regeneration of vegetation in the severe climatic conditions. Two agricultural enterprises, "Tundra" (i.e. the village of Lovozero) and "The Reindeer Herder" (the village of Krasnoshchelye), and one pilot deer-production farm "Sunrise" (at Loparskaya by Moscow – Murmansk railway) specialize in reindeer husbandry.

Due to harsh climate and short growing season, the production of vegetables, dairy products and poultry are relatively low. Local people own allotments around almost every settlement, and there is also some fur farming of silver and arctic fox.

Land in Murmansk Region can be divided into agricultural and non-agricultural (State Report...2010a). Agricultural land includes arable land, hayfields and pastures etc. According to data of January 1, 2010, the agricultural land area constituted 27,200 ha, or 0.2% of the total land area of the Murmansk Region, used as follows: agriculture (25,100 ha or 92.2% of agricultural land); settlements (700 ha or 2.6%); industry, transportation and other purposes (400 ha or 1.4%); forest land (700 ha or 2.6%); reserve lands (300 ha or 1.1%). Of the land in agricultural use the share of arable land is 77.2% (21,000 ha), hay fields and pasture 11.4%. More than half of the total agricultural land area is obtained by drainage of over-moist soils. Natural grasslands scattered in small patches along the shores of the lakes and rivers of the Kola Peninsula play no significant role in the overall structure of agricultural land.

The category of non-agricultural land includes all territories covered by waters including surface streams, shallow ponds and mires. The total area occupied by water bodies and wetlands is 6.9 mha, or 47.6% of the total land area of the Murmansk Region, made up of surface water bodies (1.19 mha) and mires (5.7 mha). Large water-covered areas are included in the categories of agricultural land (2. 37 mha) and forest land (3.78 mha) of Murmansk Region. As a percentage of the total area under water bodies and wetlands in Murmansk Region, the share of water-covered lands that are categorized as agricultural and forest land are 34.4% and 54.8% respectively.

Land categorized under "buildings and construction" includes the land occupied by residential, cultural, service, administrative as well as industrial and commercial buildings or warehouses and such structures that are necessary for their operation and maintenance. This land category covers 36,200 ha or 0.2% of the total land area of the Murmansk Region, with 18,700 of these hectares (52%) occupied by settlements. The share of land occupied by industrial buildings or used for transportation and other purposes is 15,300 ha (42.3%). Land covered by the transportation network (i.e. roads, railways, streets, forest tracks etc) total 31,100 ha, or 0.2% of the total land area of the Murmansk Region, of which 15,500 ha (49.8%) are categorized as the state forest fund land and 10,400 ha (33.4%) as land for industry, transport and other purposes.

Forest covered land occupies 5.96 mha, (41.2%) of the total land area of the Murmansk Region, divided into tree covered 5.38 mha (37.2%) and shrub covered 578,600 ha (4%).

Of forest land listed as tree covered, 5.3 mha (98.8%) are at present actually forested while 62,900 ha (1.1%) are not. Most of the forest land (5.18 mha or 96.3%) is categorized as being part of the available forest resources. 176,300 ha (3.3%) of forests are protected. At present, 361,000 ha of the total of 578,000 ha of land classified as under shrubs are, in fact, in agricultural use.

The remainder of the region's land totals over 1.5 mha (10.5%) and is distributed as follows: landfills and waste dumps (3,000 ha); sands (7,600 ha); tundra (350,900 ha); other lands (62,100 ha). Within the category "other lands", the share of the forest fund is 532,300 ha (34.9%); reserve land 527,300 ha (34.6%); industrial land 252,900 ha (16.6%); agricultural land 98,800 ha (6.5%); protected areas 93,200 ha (6.1%); and settlements 19,100 ha (1.2%).

Reindeer pasture land. Altogether in Murmansk Region 5.67 mha of land are used as reindeer pastures. These pastures are located on territories which are listed under different land categories (Ecological Atlas ... 1999, Main directions ... 2001, Forest Management Plan ... 2008b, State Report ... 2010a).

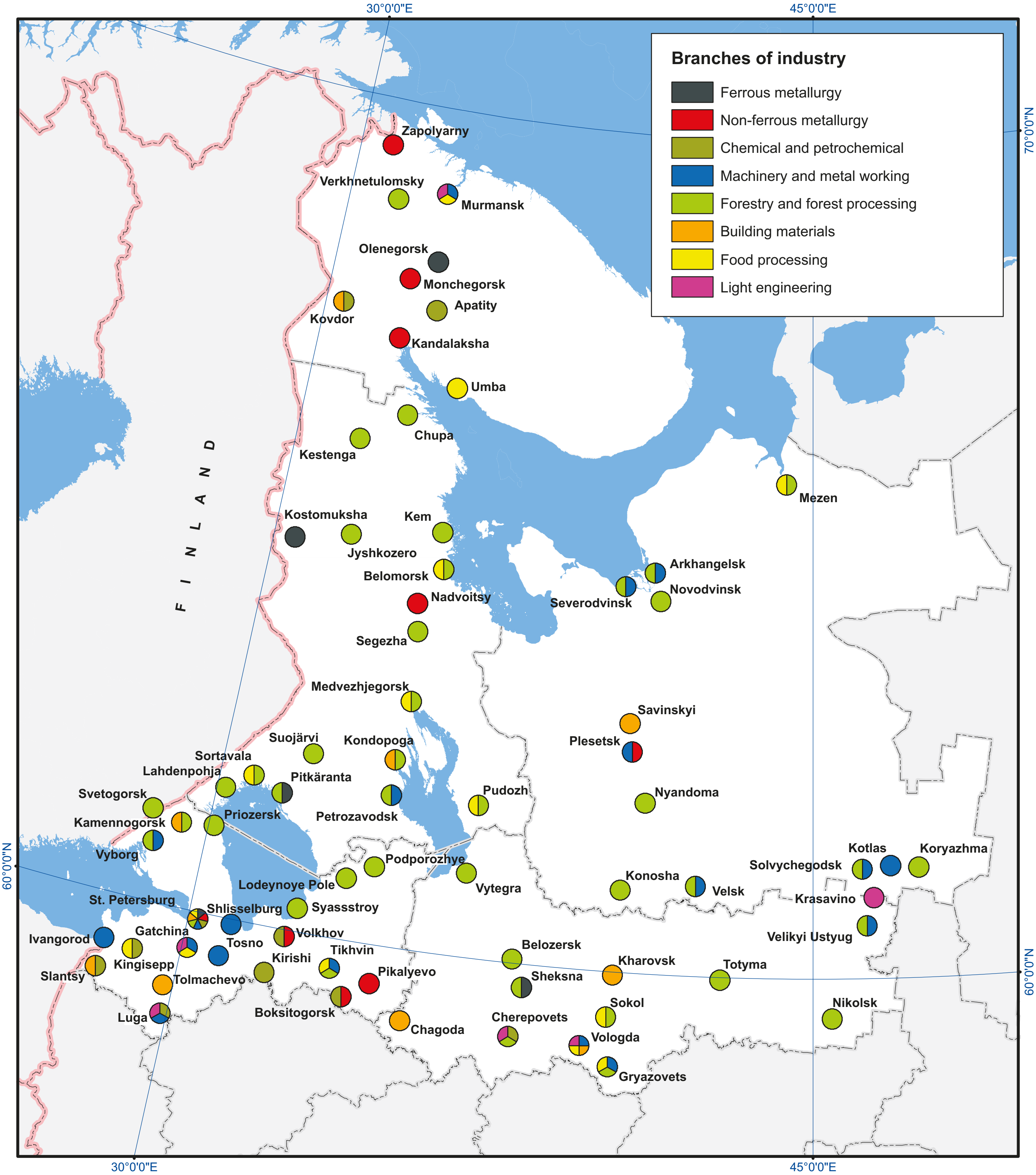


Fig. 1.8. Industrial centers in northwest Russia.

1.3. Protected areas in northwest Russia

Protected areas in the territories of northwest Russia which are included in the study, are listed in the Appendix. They are divided into several hierarchical levels depending on their protection regime.

The Russian federal law on specially protected nature areas was approved in 1995 (Federal Law…1995). According to this document with further corrections and additions (Stepanitsky 2001), protected areas in the Russian Federation are defined as "areas of land and surface water and the air space above them, where natural complexes and objects of special conservational, scientific, cultural, aesthetic, and recreational importance are located. These areas are fully or partly withdrawn from economic use on the decision of state authorities, and a special regime of protection is established for them".

According to the 1995 law, there are several principal types of protected nature areas with different legal status, protection regimes, and functions, managed by various federal and provincial agencies. These are: zapovedniks (strict nature reserves), national parks, nature parks, zakazniks (nature sanctuaries), nature monuments, as well as botanical gardens, arboretums, and healing resorts, i.e. areas where nature possesses outstanding therapeutic qualities. Below they are briefly presented and the IUCN (International Union for the Conservation of Nature) categories corresponding to them are mentioned according Krever et al. (2009) and Milovidova et al. (2011).

Strict nature reserve (or "zapovednik" in Russian) represents the oldest, best known, and most prominent protected area type. It is a strict scientific nature reserve where all economic activity is prohibited, including tourist visits, which are restricted to guided excursions in open zones. Strict nature reserves hold title to their land and fall into IUCN category Ia – managed mainly for science, or Ib – managed mainly for wilderness protection, in terms of management objectives prescribed by law. Law also requires the formation of a buffer zone around zapovedniks with restrictions imposed on land use, supervised by on-site staff. Strict nature reserves which are included in the World Network of Biosphere Reserves and promote the three mutually reinforcing functions of conservation, sustainable development, and logistic support for scientific research and education, have the status of ***biosphere nature reserves***.

National Park is a protected area managed for ecosystem protection and recreation. The Russian National Park system started in the 1970s as a part of the Forest Service and combined conservation and recreational objectives with limited forestry. As a rule, each national park has a core zone where all anthropogenic activities are prohibited, and recreational zones open for tourists, with marked tourist routes and shelters. Each national park has on-site staff and zoning regulations. The national park management bureau normally holds title only to the core zone and some other areas and falls within IUCN category II – managed mainly for ecosystem protection and recreation.

Both strict nature reserves and national parks usually cover large areas. They are managed directly from Moscow by the Directorate of Protected Area Management of the Service for Control in the Field of Natural Resources, which is under the Ministry of Natural Resources of the Russian Federation. This arrangement combines enforcement and land management under one federal agency. In some strict nature reserves, buffer zones are under the administration of provincial governments. Each zapovednik and national park has a management institution in the field (protected area administration) that answers directly to the national agency in Moscow. Typically, each unit has administrative, enforcement, research, and environmental education departments staffed with professionally trained people. Some of the better managed strict nature reserves have brought nearby lower-level protected areas under their jurisdiction or simply conduct law enforcement in those areas.

There are other protected areas that do not have the same status as the strict nature reserves and national parks but are so numerous that they are still important in nature conservation. Such areas are established either by federal or, more frequently, by provincial (republic or region) government and by municipalities.

Zakaznik, which can be translated as a wildlife refuge, nature sanctuary or nature reserve, is a protected area managed mainly for habitat or species conservation, i.e. established to protect zoological, botanical or landscape features, or in many cases combinations of these. In contrast with the first two categories, zakazniks fall within IUCN category IV– managed mainly for conservation through management intervention,because land titles are usually not withdrawn from landowners, tenants or users (forestry enterprises or farms), but conservation restrictions are imposed on land use. Some zakazniks correspond to category VI – managed mainly for the sustainable use of natural ecosystems (Milovidova et al. 2011). This is the most numerous, flexible and diverse type of protected area in northwest Russia, established most frequently by provincial governments. In contrast with strict nature reserves and national parks, zakazniks are usually smaller and have no staff, except a few federal zakazniks which are staffed with 2-3 patrolling rangers. Zakazniks can be either permanent or temporary. In the latter case, they are created for a limited period (usually 10-15 years). Although Russian federal law on specially protected nature areas (1995) makes no mention of the establishment of temporary zakazniks, they are nevertheless common in northwest Russia (Aksenov et al. 1999).

Nature park is an analogue of the national park at the regional level. It is a protected area established by provincial (republic or region) administration that, besides biodiversity value, has some scenic value for tourism. Usually, some of the territory is removed from land tenants' use, though they may retain use of the remainder. Corresponding IUCN categories: II – managed mainly for ecosystem protection and recreation (Milovidova et al. 2011).

Nature monument is a small protected area, usually established locally by a municipality to protect geological, zoological, botanical, or landscape features on limited acreage. The tenants in these areas retain use of the land. Corresponding IUCN categories: III– managed mainly for conservation of specific natural features (Milovidova et al. 2011).

Nature resort (healing landscape) is a protected area established for therapeutic aims. Nature resorts (typically situated on beaches or in areas rich in mineral springs) have a separate management system dictated by the needs of the institutions and the clients using them for medical and recreational purposes.

Botanical garden, arboretum is a protected area established for conservational and educational purposes. Usually it is attached to a university or research institute.

In **Arkhangelsk Region** as a whole almost 8 mha (including marine waters currently in federal possession) are officially protected by the network of 105 protected areas at both the federal and regional levels, and 4 protected areas of local level.

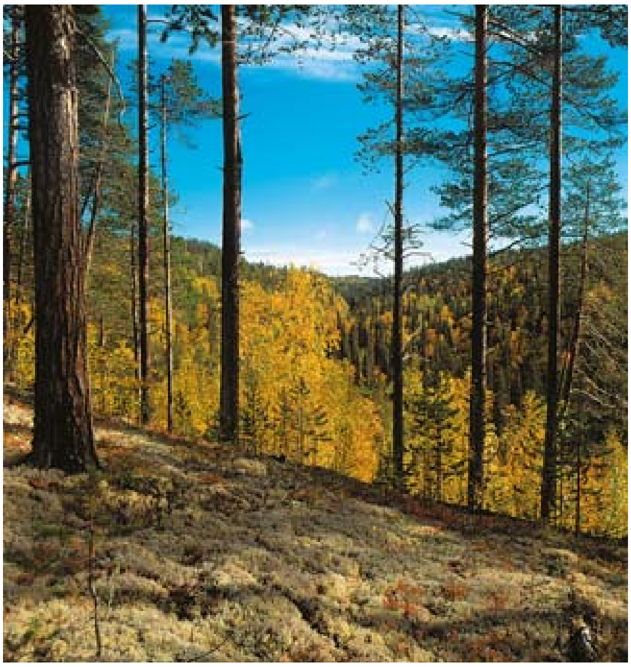
Protected areas are distributed throughout Arkhangelsk Region very unevenly. Northern and northwestern parts have relatively large protected areas, each exceeding 100,000 ha. In southern parts protected areas are small, with an average area of 2-30 ha. The share of protected areas in relation to the total area of municipalities is around 5% in the southeast, 2-3% in the central part, 9-11% in the west, and 23-37% in the northwest of Arkhangelsk Region.

Protected areas of the federal level are represented by the Pinega Strict Nature Reserve, two national parks, the National Park Kenozero and the Onega branch of the National Park Vodlozero, and the state biological nature reserve Siysky. Two federal protected areas, the National Park Russian Arctic and the state zakaznik Franz Josef Land Archipelago, which are administered by Arkhangelsk Region, are located outside the territory of this study and are not further discussed in this publication.

The planned National Park Onega Pomorye covering 201,668 ha on the Onega Peninsula in the White Sea, was established 26.02.2013. In 2008, after detailed ecological studies, the boundaries of the proposed national park were defined and all the land plots to be included in it have been registered in the State Census of agricultural land. This national park was included in the priority list of protected areas of the Ministry of Natural Resources and Ecology of the Russian Federation, planned for official establishment by 2010, and in the Program for Development of the Federal Protected Area Network by 2020.

99 protected areas of the regional level cover a total area of almost 1.7 mha. They include 32 zakazniks with a total area of 1.67 mha and 67 nature monuments, most of which are very small. The zakazniks include 22 biological zakazniks, 8 landscape zakazniks, one geological zakaznik and one hydrological zakaznik. The group of nature monuments includes 29 botanical, 7 hydrological, 4 geological, 2 landscape, and 25 complex nature monuments.

Protected areas of local level (established by municipalities) are administered by the Agency of Natural Resources and Environment of Arkhangelsk Region. For more efficient management of regional level protected areas, the regional government agency, "Directorate of protected areas of the regional level in Arkhangelsk Region" (under the jurisdiction of the Agency of Natural Resources and Environment of Arkhangelsk Region) was established in December, 2005. In 2010, it was combined with the State Steering Committee "Environmental Protection Center of Arkhangelsk Region".



Lapland Strict Nature Reserve is the oldest protected area in northwest Russia. It was established 17th of January 1930, and since that time its status and protection regime have changed several times. In 1951, Lapland Strict Nature Reserve was abolished, but re-established in 1958. In the interim years, forest logging was started in the formerly protected territory. During the period 1961-1965, the reserve existed as a branch of the Kandalakshsa Strict Nature Reserve, which is situated on the shore of the White Sea. In 1983, the territory of Lapland Strict Nature Reserve was expanded to offset the impact of industrial emissions from the steel plant in the city of Monchegorsk. In 1985, Lapland Strict Nature Reserve was awarded biosphere nature reserve status. Photo: Vladimir Latka.

The network of protected areas in **Vologda Region** with a total area of 787,300 ha incorporates two federal protected areas, the Darwin Strict Nature Reserve with its protective belt or buffer zone (part of which lies in the adjacent Yaroslavl Region) and the National Park Russky Sever (or The Russian North); 163 protected areas of regional level, including 78 zakazniks (of these 57 landscape zakazniks); 82 nature monuments; one preserved natural complex; two recreational areas; 118 protected wetlands; and 7 protected areas of local importance. Landscape zakazniks have been established in both typical and unique natural complexes of the region. A set of landscape zakazniks scattered in every biogeographical sub-zone aims at reflecting the diversity of the natural habitats which occur in Vologda Region (Milovidova et al. 2011). Some of these landscape zakazniks are combined with forest genetic reserves. The remains of the untouched spruce-dominated natural forests with typical species pools of plants, animals and fungi, including many rare and red-listed ones, can be found only in three landscape zakazniks, Atleka, Verkhne-Andomsky, and Verkhovyna Forest.

Hydrological zakazniks are aimed at protecting the most interesting types of water bodies, like karst lakes, underground streams, springs and their forest surroundings. Karst lakes are protected in the hydrological zakazniks Shimozero, Kushtozero, Luhtozero and Ezhozero, situated in the northeast of Vologda Region (Vytegra municipality), in an area of irregular limestone containing deep fissures and sinkholes and characterized by underground caves and streams. The hydrological zakaznik Klyuchi (Springs) in the valley of the river Kolpa, Babaevsk municipality, has been established in an area rich in springs resulting from pressure from rising groundwater.

The geological zakaznik Verkhnyaya Strelna represents high cliffs with outcrops of bedrock in the lower reaches of the River Strelna, Velikyi Ustyug municipality. Botanical zakazniks are situated in three municipalities of Vologda Region: Totemsky, Tarnogsky, and Babooshkinsky. Some zakazniks are situated in scenic areas and dedicated to recreation, e.g. Pine Forest Ikonnyi in Babooshkinsky municipality, Spassky Forest in Tarnogsky municipality, and Lopata Forest in Nickolsky municipality.

The category of nature monuments forms the largest group of protected areas in Vologda Region. They are designed to protect small nature units and manmade objects which are either unique or have high ecological, scientific, cultural, or aesthetic values. Vologda Region has different kinds of nature monuments, viz.: landscape, geological, hydrological and botanical. Landscape nature monuments are established for small scenic forest patches located in densely populated areas, near settlements or along river banks, which are attractive and easily accessible to the public. Geological monuments usually represent unique exposures of pre-Quaternary bedrock, or large erratic boulders from the melting of the glacial ice. There are only two hydrological nature monuments, Druzhinskie Yamy, comprising sinkholes in the karst area in

Vashkinsk municipality, and Lake Mitvorovo in Belozersk municipality. Finally, the category of botanical monuments includes certain forest sites, mires and ponds which harbour rare plant species, including those listed in the Red Book of Vologda Region (2004).

Protected areas of local level are represented in Vologda Region by 13 nature reserves, formed by the decisions of, and governed by, local municipalities. According to the Vologda law "On Specially Protected Nature Areas", these nature reserves are intended for the preservation, restoration or reproduction of threatened natural habitats and for sustainable use as recreational areas, like city forests and city parks designed for public recreation. Pine forest Ivonynsky, a patch of old-growth forest in Verhovazhsky municipality, and Belyie Istoki, an area rich in natural creeks in the Vytegra municipality, are both recreational reserves and examples of protected threatened natural habitats. A Peace Park in the city of Vologda is an example of a protected city park which maintains rare and threatened plants. Also, municipal nature reserves exist in the Nyuksa, Gryazovets and Sheksna municipalities, and in the green zone forests surrounding some cities and villages.

In the **Republic of Karelia** there are 145 protected areas totaling 872,500 ha. They include 3 strict nature reserves, Kivach, Kostomuksha and Kandalaksha, the latter partly extending into Murmansk Region, of a total area of 60,100 ha; 3 national parks, Paanajärvi, Kalevala and Vodlozero, the latter partly in Arkhangelsk Region, covering 309,400 ha; one nature park, Valaam of 24,700 ha; 32 zakazniks totaling 375,300 ha, 2 of them of federal and 30 of regional level; and 103 nature monuments totaling 37,300 ha, including 63 wetlands. In addition, the Republic of Karelia has about 3,000 ha of forest as part of the spa nature resort Martsialnyie Vody, and 13,000 ha of land in the buffer zones of the Kivach Strict Nature Reserve and the Paanajärvi National Park. Of the above, nine (all the strict nature reserves and national parks, 3 zakazniks and one nature resort) are protected areas of federal level. They occupy a total area of 453,700 ha. The remainder are protected areas of regional level, covering a total of 418,800 ha.

Murmansk Region has, at present, 2 strict nature reserves, Kandalaksha (70,530 ha) and Pasvik (14,727 ha); one Biosphere Strict Nature Reserve Lapland (278,435 ha) and its buffer zone (27,998 ha): 10 zakazniks (3 federal and 7 regional), of which 4 are game reserves, 2 are fishery reserves and 4 are complex zakazniks, totaling 787,100 ha. One large complex zakaznik, Lapland Forest with an area of 142,100 ha (see chapter 4) is in preparation. In addition, there are 50 nature monuments (4 federal and 46 regional, altogether 4,500 ha); one protected area of 1,250 ha which belongs to the Polar-Alpine Botanical Garden and Institute of the Kola Center of Russian Academy of Sciences, and the Eyhfeld Grove, a local nature monument of 0.3 ha.

There are 1,156,600 ha (or 7.9% of the total area) of Murmansk Region in protected areas. According to the provisions of these protected areas, their total area is in fact greater, but less than half of this true total has a regime that protects against the most harmful human activities such as like logging, mining and construction of roads, electric lines, etc. (see Chapter 3). Thus, although the share of protected areas in Murmansk Region is not the lowest in northwest Russia, the current status of the network there can be characterized as one of crisis. The main reasons for this conclusion are as follows: (1) the small size and number of protected areas which have an adequate protection regime (at present only the strict nature reserves, three zakazniks Kolvitsa, Seydyauvr and Kutsa, and some small nature monuments meet criteria for real protection that guarantee their survival); (2) the lack of an effective mechanism for the maintenance of the protection regime in other protected areas; (3) reductions in size of protected areas (reduction of 29% during the period 1990 - 2000) mostly due to the expiration of temporary protected areas; (4) the cessation of creation of new strict nature reserves, complex zakaznics and nature parks in 1994; and (5) the absence of national parks, which could be a very effective form of nature conservation and sustainable use of natural resources in Murmansk Region.

The current crisis situation is the result both of natural factors, such as the complexity of landscape structure in Murmansk Region, which has two biogeographical zones, tundra and taiga, mountains and an extensive coastline; and socio-economic factors, such as the lack of integration of protected areas into the economic system of the region, the common view that protected areas are useless or even harmful for the local economy, and the very small number of qualified personnel in the field of nature protection.

All these factors are also common in the whole Russian Federation. However, in the Murmansk Region the situation is complicated by additional, historical reasons. First, the traditional orientation of the region is primarily to develop logging, mining, and reindeer husbandry. Traditionally, environmental actions have been focused on the struggle against air and water pollution, but not on the establishment of extended protected areas excluded from industrial development. Thus, there has been a drastic reduction of almost one third in the area under protection, which is more than in any other Russian region during the last two decades.

The in-depth study of nature in the **City of St. Petersburg** and its environs, aimed towards sustainable use and protection of natural resources, has a long tradition. Early research was conducted by professor Vasily Dokuchaev in 1870. In 1908, Dokuchaev started attempts to establish nature reserves near St. Petersburg, which became the prototypes of the current protected areas.

A network of zakazniks for game purposes on the territory of St. Petersburg and **Leningrad Region** was established in 1928 (Red Data Book of Nature of the Leningrad Region 1999). First proposals to protect the lower reaches of the Oredezh River and valleys of the rivers Ragusha and Luga appeared in the late 1920s-early 1930s. In the 1970s, scientific proposals for establishing a zakaznik network in Leningrad Region were put forward. The Executive Committee of Leningrad Region (Lenoblispolkom) passed Resolution No. 145 on 29 March 1976: "On the establishment of zakazniks and assignment of nature monument status to valuable natural areas in Leningrad Region". In accordance with this resolution, 17 zakazniks and 19 nature monuments were set up, and 5 salmon spawning-grounds, 42 animal and 48 plant species were placed under protection. This resolution created the foundation for further nature conservation activity in Leningrad Region. In 1980, the Nizhneswirskiy zakaznik was transformed into a strict nature reserve of the same name, and the zakaznik Mshinskoe mire was assigned federal status.

In subsequent years, new proposals have been put forward concerning the establishment of protected areas and the principles of their designation and development. During the period 1986-1988, there were proposals for 30 new zakazniks and nature monuments. So far, 5 of these have been granted protected area status.

In 1990-1991, a further 60 territories were thoroughly studied to find out which deserved protection. As a result, additional grounds were developed to establish 1 nature park, 3 strict nature reserves, 27 zakazniks and 7 nature monuments.

In 1993-1996, extensive work clarified the boundaries and areas of existing protected areas for the preparation of cartographic materials, descriptions and regulations. The results were reflected in the Leningrad Region government resolution № 494 on 12/26/96. At the same time, proposals for the establishment of 7 new zakazniks, two nature monuments, and one nature park Veps Forest were prepared and sent to the government of Leningrad Region. A proposal for the establishment of a Strict Nature Reserve Ingermanlandsky, in the easternmost part of the Gulf of Finland, was prepared and approved in all relevant state departments. In 1998-1999, proposals were made for the establishment of 12 protected areas in the coastal zone of the Gulf of Finland and in the north of the Karelian Isthmus.

The existing 45 protected areas occupy a total of 573,500 ha. They include:

- 2 protected areas of federal level totaling 102,000 ha, Nizhneswirskiy Strict Nature Reserve (41,600 ha, of which 5,000 ha of Lake Ladoga) and the federal zakaznik Mshinskoye Mire (60,400 ha);

- 39 protected areas of regional level totaling 467,200 ha. Of these, Veps Forest Nature Park (189,100 ha), 23 zakazniks (total area 272,100 ha including 97,960 ha of marine waters in the Gulf of Finland), and 15 nature monuments (5,991 ha).

- 4 protected areas of local level totaling 4,277 ha.

Five protected areas in Leningrad Region with a total area of 257,200 ha have the status of wetlands of international importance in accordance with the International Ramsar Agreement ("Ramsar sites"). Of these, four protected areas, Berezovye Islands, Kurgalsky Peninsula, Lebyazhye, and Mshinskoye Mire System are entirely integrated into the existing protected areas, either on the federal, or regional levels. The fifth, Swir Bay of Lake Ladoga, is partially included in the Nizhneswirsky Strict Nature Reserve.

Four protected areas of the Leningrad Region with a total area of 132,900 ha are included in the system of protected areas of the Baltic Sea (HELCOM). One protected area, zakaznik Lindulovskaya Grove (986 ha), is a part of the UNESCO World Heritage Site "Historical centre of St. Petersburg and related groups of monuments."

In the **City of St. Petersburg** there are seven protected areas totaling 2,542 ha, or 1.8% of St. Petersburg's territory, including three regional zakazniks and 4 nature monuments. Establishment of 9 additional protected areas is in progress, according to the Law of St. Petersburg № 728-99 of 22.12.2005 "On the Master Plan for St. Petersburg and the boundaries of the zones of protection of cultural heritage in the territory of St. Petersburg". They are: 5 zakazniks, 2 nature monuments, one therapeutic area, and one natural-historical park with a total area of 17,710 ha, accounting for 12.3% of the territory of the City of St. Petersburg.

The analysis of representativeness of the existing and planned network of protected areas in northwest Russia is given in detail in Chapter 3. Full list of the existing protected areas in the study area is given in the Appendix

There are still intact forest landscapes fragmented by lakes in northwest Russia stretching in every direction to the horison. Photo: Sergey Osipov.

2. METHODS FOR DELINEATION OF HIGH CONSERVATION VALUE AREAS

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Editor: Dmitry Aksenov

2.1. Methodological approach to mapping of high conservation value areas

2.1.1. Main definitions

The aim of this study is mapping of nature areas of high conservation value (HCV areas) in northwest Russia. They may be of different size and on different levels of organization, e.g. *biotopes, complexes of biotopes, biogeocenoses* as well as other units, like *associations* and *ecosystems* which possess one or more clear characteristics of high conservation value.

Terms used for concepts of ecosystem, biogeocenosis, biotope, habitat, etc., differ markedly in Russian and Western literature. Since our goal was to identify more or less generalized units which could be delimited as areas of high conservation value, we avoid using the term "ecosystem" only, because it lacks the spatial delimitation that is very important for mapping aims. As an area of high conservation value, we use natural sites of different size, ranking from single key-habitat to complexes of several forest terrains, or a vast mire area in a genetically uniform territory. Below we provide a brief glossary of some terms used in this study.

In Russian literature, a natural area within a territory dominated entirely by the same genetic forms of mesorelief is usually denoted by the term "**biogeocenosis**", which is defined as follows: "*Biogeocenosis is a complex of homogeneous natural phenomena (atmosphere, rocks, plants, animals, microorganisms, soil and hydrological conditions) in a particular area. The constituents of the complex interact in their own way and exhibit characteristic types of metabolism and energy exchange between one another and with other natural phenomena. The complex is a constantly changing and evolving, internally contradictory dialectical integrity*" (Biotic diversity …2003).

The complex spatial and temporal structures of biogeocenosis and the absence of direct correspondences between the elements of its constituent systems make the division of biogeocenosis into its elements quite difficult. At present, there are many ways to such division (Mirkin & Naumova 1998) depending on the aim of the study. Different biocenotic components can be used as key parameters, for instance, species composition of ground vegetation (flora component), animal species pool (fauna component), landscape structure (landscape component), etc. In this study, we use the *biotope* level which is equivalent to the *habitat* level according to EUNIS Palaearctic Habitats Classification (Davies et al. 2004). This approach is the most suitable in our study focused on the analysis of the existing network of protected areas in northwest Russia and its improvement towards covering all types of nature biotopes. The term "*habitat*", however, is a static definition which does not cover its dynamics, in particular, successional stages and migrations of birds and animals. For a more precise classification of high conservation value areas, we try to use all these characteristics in addition to the standard characteristics of the habitat given in the EUNIS Palaearctic Habitats Classification.

Biotope is defined in this study as "*an ecologically homogeneous constituent of a biocenotic and abiotic environment*". This definition is a slightly modified version of V.N. Sukachev, widely accepted in Russian literature: "*Biotope is an ecologically homogeneous constituent of a biocenotic environment which corresponds to a phytocenosis or its components and provides a habitat (niche) for one or more animal or plant species*" (Sukachev 1964, Novikov 1979, Reimers 1990). This definition corresponds with the definition for **habitat** given in the International and European directives (Habitats Directive 1992, Bern

Convention 1996, Devillers et al. 1996, Corine Biotopes, The Interpretation Manual of European Union Habitats – EUR 27, etc.): "*natural habitats" means terrestrial or aquatic areas distinguished by geographic, abiotic and biotic features, whether entirely natural or semi-natural*" and in EUNIS Habitats Classification (Davies et al. 2004): *"areas with particular environmental conditions that are sufficiently uniform to support a characteristic assemblage of organisms"*. All these definitions are similar to the term "**biogeocenosis**". To identify natural boundaries of HCV areas in this study we used most often the boundaries delimited within ground vegetation cover of phytocenoses, forest facies and forest ecosites.

Ground vegetation – a set of plant associations sharing the same territory **–** is the primary characteristic for most of the habitats discussed in this study. We used vegetation classification based on the ecological-floristic criteria (the Braun-Blanquet approach), the Northern Tradition based on dominants (Whittaker 1962). Despite the obvious faults of this vegetation classification (Whittaker 1962, Aleksandrova 1969, Mirkin 1989), we found it most useful in our study, which is chiefly focused on practical issues rather than on investigations in detailed floristic classification of the study area.

Phytocenosis. A community of plant organisms that are part of a biogeocenosis and form their own internal medium. Although according to certain theories (e.g. the paradigm of vegetation continuum, Mirkin et al. 2001), delimitation of the phytocenoses within ground vegetation cover seems rather artificial, we used this term for practical reasons of mapping in this study.

Forest facies. Forest biogeocenosis within a constituent of the genetic form of mesorelief**.**

Forest landscape ecosite. A complex of forest biogeocenoses existing in contact with one another and occupying a genetic form of mesorelief.

In this study we use two types of **complexes of intact biotopes**, viz: intact nature landscapes and intact nature tracts, differing in size but sharing the main characteristics: minimal anthropogenic disturbance, and maintaining structure and organization maximally close to the natural.

Intact nature landscapes, both terrestrial and marine. These are unbroken expanses of natural ecosystems that show no signs of significant human activity and are large enough to maintain all native biodiversity, including viable populations of wide-ranging species. They include biotopes of different types, e.g. territories similar in their overall spectrum of ecological parameters within different super-landscape units of physico-geographic demarcation, e.g. large areas of minimally transformed forest including small open mires, rivers and lakes.

Intact nature tracts, a group of biotopes which belong to the same type and alternate regularly within a territory dominated entirely by the same genetic forms of mesorelief, e.g. a large forest stand (forest tract, or forest massif), an extended mire (mire-massif or wetland tract) with minimal disturbance caused by humans.

Habitat. In this study we use this term to indicate the habitat or microhabitat of a particular species, or *"an environment defined by specific abiotic and biotic factors, in which the species lives at any stage of its biological cycle"* (Habitats Directive 1992). In this study, however, our use of the term "habitat" is not in entire accordance with the definition given by the European directives because for many rare and threatened plant species we do not possess sufficient ecological data fully describing the entire habitat and microhabitat where the species has been found.

Key habitats – biotopes or the parts of biotopes which possess high conservation value or which are the most important for the survival of particular rare and threatened species (e.g. nesting places for threatened birds, spawning areas in rivers, etc.)

Association or Community – a group of populations belonging to different species (animals, plants, fungi) sharing the same ecological niche. Community is a part of **ecosystem** which is considered separately from its abiotic components. We use the terms "association" or "community" to highlight either small ecological groups (e.g. an epiphytic lichen community on a tree trunk) or, vice versa, large units (e.g. the taiga biome).

Rare association or rare community – an ecological group with naturally restricted distribution in an area, or formerly widely distributed but having become rare as a result of human impact. Communities can be rare on the global or the local scale. Most of the rare communities are threatened and have a high extinction risk.

Rare species – species which have limited area of distribution, extent of occurrence or population

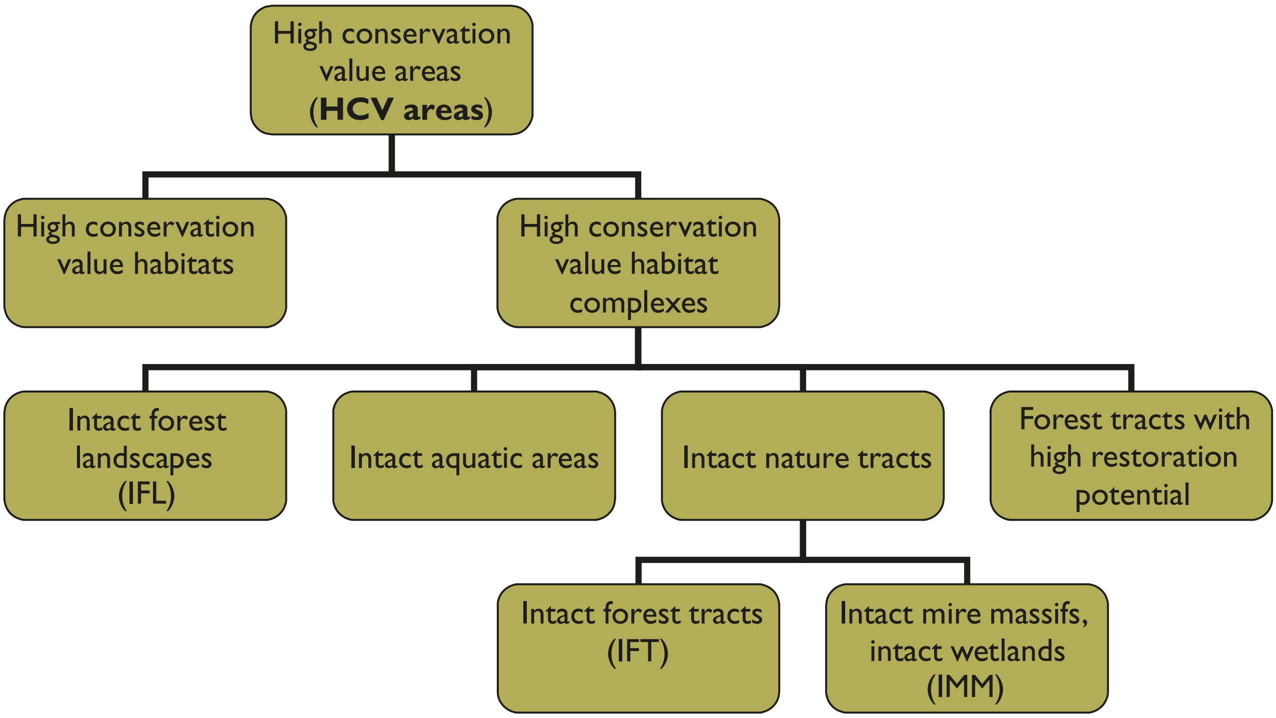

Fig. 2.1. Types of high conservation value natural areas used in this study.

size in the studied territory due to both natural factors and factors caused by humans. In the Russian red lists, both in the Red Book of the Russian Federation (2000, 2008) and in regional red lists, the following categories for threatened species are used:

1. Endangered – a taxon which, without conservation measures, faces a very high risk of extinction in the wild due to declining population size and area of occurrence.
2. Vulnerable – a taxon with clear reduction of population size and area of occurrence which is considered to be facing the risk of extinction in the wild in the immediate future.
3. Rare species and populations – a taxon with limited extent of occurrence, or with sparse distribution and low population in an area due either to natural reasons, or for reasons which are unclear.

Conservation value – the importance of the particular nature object for nature conservation, maintaining the stability of the environment and revitalization of natural resources. In this study, we pay special attention to the sustainable use of intact and minimally transformed natural areas in order to obtain ecosystem services important for the local people in their economic, social and cultural life. This means that natural objects preserved in a particular territory may have different conservation value from the point of view of regional goals of nature conservation. Excluding industrial activity from all the areas which possess features of intact nature seems impossible, but the regional strategy of nature conservation should be aimed at establishing a network of protected areas sufficient to maintain natural processes in every region. The total area of the protected areas must be limited, but enough to guarantee preservation of natural biodiversity. Intact biotopes, complexes of biotopes and entire intact landscapes, if they exist in a region, definitely have priority in the regional programs for the establishment of protected areas. They possess the potential to maintain themselves without special measures other than restriction of the most harmful human activities like mining, felling, construction, etc. Man-made ecosystems, even if their biodiversity is quite large, usually degenerate quickly if support measures are withdrawn. Of course, in many regions of Russia, e.g. in the steppe zone (Tishkov 2005), the size of intact natural areas is so small that conservation of biodiversity is already impossible without saving agricultural landscapes. In northwest Russia, however, the areas of intact and semi-natural ecosystems seem to be large enough to focus this study only on them, and not take into consideration man-made ecosystems at all. Similarly, we consider the **intact** natural ecosystem more valuable than such semi-natural systems which have formed naturally on sites of former anthropogenic disturbances (van Andel 1994, Smirnova & Shaposhnikov 1999). For a full list of the criteria for conservation value, see 2.1.3. below.

Minimally transformed ecosystems – ecosystems that have been formed under the influence of natural factors, without any human management. We fully accept the point of view of Yaroshenko et al. (2001) that forests and other natural ecosystems that are absolutely wild and completely unaffected by human development activities no longer exist anywhere in the world. All present day forests display some degree of human influence, if only from transboundary air pollution or hunting. And in the context of this study, we use the term "intact forest landscapes", "intact forest tracts", "intact mire massifs", etc., to mean entire areas or natural units with either no visible signs of significant human activity, or disturbed by human activities only marginally, in such degree that these disturbances have not destroyed natural processes.

2.1.2. Classification of biotopes

To integrate the network of protected areas in northwest Russia into the Pan-European network of protected areas, we use the EUNIS Habitat Classification (Davies et al. 2004), where the following types are listed:

A	Marine habitats
B	Coastal habitats
C	Inland surface waters
D	Mires, bogs and fens
E	Grasslands and lands dominated by forbs, mosses or lichens
F	Heathland, scrub and tundra
G	Woodland, forest and other wooded land
H	Inland unvegetated or sparsely vegetated habitats
I	Regularly or recently cultivated agricultural, horticultural and domestic habitats
J	Constructed, industrial and other artificial habitats

In this study, we have slightly moderated this list for better achieving our aims in accordance with the specifity of the study area. Thus, we unite the categories A and C into one category, "Aquatic biotopes". In the category B (coastal habitats) we include complexes of biotopes which unite terrestrial coastal biotopes and adjacent parts of some aquatic biotopes. Some of the "coastal habitats" sensu the EUNIS classification, we include in other categories, e.g. coastal meadows in category E, "Meadows and sites covered with tall grasses, mosses or lichens". We consider the category H as biotopes with a prevalence of the abiotic component. Categories I and J are not included in the analysis because they are not considered relevant to the study. Thus, with these modifications, the classification of biotopes considered in this study is the following:

- Aquatic biotopes
- Coastal biotopes
- Mires, bogs and fens
- Meadows
- Tundras
- Forests
- Biotopes with a prevalence of the abiotic component

In addition we use the category "valuable biotopes" and other biotopes which do not fit into this classification scheme:

1. **Complexes of biotopes**:
    - Intact nature landscapes (in this study we have found intact natural landscapes only in the forest zone. For that reason henceforth we call them **intact forest landscapes**.
    - Intact aquatic areas (have not been covered by this study).
    - Intact terrestrial areas smaller than landscapes – intact forest massifs or **intact forest tracts**, and **intact mire massifs**.
    - Forest or mire massifs with high restoration potential (in this study we have studied only **forest tracts with high restoration potential**).

2. **Key biotopes, which are seasonal key habitats for animals.**

3. **Habitats of rare and threatened species of animals, plants, fungi and lichens.**

2.1.3. Principles for selection of biotopes and complexes of biotopes of high conservation value

To be considered as an area of high conservation value, nature areas analyzed in this study must meet one or more criteria of conservation value listed below:

A. Uniqueness. In accordance with the meaning of the word "unique", this includes natural objects that occur in only one place and have no analogues in the study area. Usually they cover only small areas. This implies the vulnerability of these natural objects and irreparability of their loss. By itself, uniqueness is not a sign of the value of a community for conservation or other functions but, as a rule, these unique objects also meet other conservation criteria, as listed below.

B. Rarity. The essential criterion is the restricted area of occurrence and the limited size of the area occupied by the community due to both human and natural causes (Krestov & Verkholat 2003). A direct consequence of this is the vulnerability of these communities, since the area of the destructive factors is comparable or exceeds the area occupied by the community, so it can be destroyed by even a minor violation. There are various floristic features of particular sites that can be considered indicative of rarity. They will be discussed below in relation to the selected habitats. The analysis also includes communities which should be considered as regionally rare due to geographic factors (e.g. for communities on the limit of their natural distribution areas), topography, micro-climatic conditions, etc., or caused by anthropogenic effect. For instance, the intact forest landscapes identified in this study usually have a distinct southern edge of a clearly anthropogenic character, i.e. in the south of the study area old-growth forests have become very rare due to deforestation caused by humans on a vast scale.

C. Size. Intact forest landscapes must be large enough to maintain all native biodiversity. Researchers recognize the special value of large natural areas for preserving all strata of biological diversity. (McCloskey & Spalding 1989, Bryant et al. 1997, Noss 1999, Yaroshenko 1999). For many cases of conservation, reserve size is vital to success. Only those natural areas which are large enough, include viable populations of wide-ranging species and maintain the natural dynamics of forest ecosystems associated with both large-scale and small-scale disturbances. Also, the central parts of large reserves are better protected from so-called edge effects, i.e. influence by disturbance of neighbouring areas.

D. Forests and mires with environment protection functions. This category includes forests that have specific safety functions, including those of water protection, erosion control, fire protection and other similar values. Wetland habitats have primarily water conservation functions, like flow control, maintenance of water purity, etc.

E. Maintaining natural resources. Here we include natural objects that are of importance for sustainable use of renewable exhaustible natural resources by local people. The preservation of these objects allows the maintenance and reproduction of these resources. This may be wintering areas of elk, sites of geese molting, salmon spawning areas, or forest sites especially rich in non-timber forest resources: plants, mushrooms, berries, etc.

F. High level of biodiversity. This concerns both the species diversity (α-diversity) and community diversity (β-diversity). Nowadays it is common knowledge that high α-diversity in communities is a very important factor in their maintenance because a community with a large internal variety is more resistant to external influences and adapts more easily to changing environmental conditions (Tilman 1999). In addition, there is a principle of more effective conservation of resources – keeping a smaller area we provide a large species pool to be protected.

G. Presence of rare species. Ensuring the protection of rare species is an absolute requirement of the Russian legislation. Rare species are considered as the most vulnerable components of biodiversity and the most sensitive indicator of its integrated adverse changes. Rare species may also serve as indicators of high species richness of an area because the habitats of rare species usually meet the criterion of high species diversity.

H. Key seasonal habitats for animals. Certain periods are crucial in the biological cycle of each animal species, like hibernation, migration, reproduction, surviving deep snow cover and lack of food, etc. Animals usually survive during these periods in particular biotopes, or key habitats, that provide environmental conditions to which each individual species has adapted as a result of long-term evolution. At these times the animals are most vulnerable, so even a minor disturbance of these key habitats can result in a decline in the distribution area of a particular species or, in the worst cases, to irreparable consequences for populations, leading to regional extinction.

I. Intactness, i.e. the absence of human disturbance (see 2.1.1. above). This particular quality of a natural landscape cannot be artificially restored. Intact natural systems tend to have greater environmental sustainability and higher biodiversity at all levels as compared to natural systems affected by disturbances caused by humans, and man-made systems (Eastern European forests ... 2004, Smirnova et al. 2005, Tilman 1999, Noss 1999, Yaroshenko et al. 1998, Yaroshenko et al. 2001). In this study we make no direct measurements of the qualities of biodiversity in the areas considered as intact according to interpretation of the satellite images, because even the extent and boundaries of these areas are poorly known. Therefore, absence of visible man-made infrastructures within these areas serves as the main criteria for selecting them for further analysis. The acceptable level of disturbance is determined separately for each type of intact forest landscapes, intact forest tracts and intact mire massifs (see section 2.3).

J. Scientific value. Areas which have maintained their natural state are suitable for integrated environmental monitoring and for conducting scientific research on natural processes in ecosystems. They are of scientific value and can be used for resolving practical questions related to natural resource management and environmental protection. They also include preservation of particular objects which may have scientific value in the future.

The criteria of high conservation value listed above might be applicable both to complexes of biotopes, and to particular individual biotopes. Biotopes and complexes of biotopes that are common and may be considered typical for particular areas are excluded from this study if they do not meet at least one of these criteria. Areas and sites of special historical, cultural and religious value are also excluded from this study as requiring too much work involving experts on these subjects.

2.1.4. Nature areas of high conservation value used for mapping and analysis

Nature areas for consideration as high conservational value objects deserving analysis in this study were selected by regional experts of the Arkhangelsk, Leningrad, Murmansk, and Vologda Regions, the Republic of Karelia and the City of St. Petersburg, listed by name on the final pages. Generally, only those nature areas for which we possess enough information to delineate them entirely on the map are included in the study. Some insufficiently known sites are excluded due to our inability to map them in their entirety.

The ***Turyi Cape*** on the White Sea coast of Murmansk Region is considered a natural area of high conservation value. It conforms with the following conservation value criteria: **B.** Rarity (rare environmental factors determine the occurrence of rare plant communities, strictly confined to this particular biotope); **F.** High biodiversity; and **G.** Presence of rare species (high diversity of habitat conditions in this small area has determined a high diversity of vegetation, and the specificity of these conditions allows the presence of a significant number of rare plant species). Two of these species, Arctic sunflower (*Helianthemum arcticum*) and the dandelion species *Taraxacum leucoglossum*, are endemic here. Therefore, this natural area also meets the criteria **A.** Uniqueness and **J.** Scientific value. This site is situated within the Kandalaksha Nature Reserve and represents one of the permanent study areas of the Polar-Alpine Botanical Garden Institute of the Kola Research Centre of the Russian Academy of Sciences. Long-term population studies of rare plant species have been conducted here. Photo: Gennady Aleksandrov.

Priority has been given to the natural features that can be considered valuable on the international level, primarily to intact forests and wetlands. However, every region in the study area has its own approach for choosing the most valuable natural objects. For instance, in Vologda Region, aapa mires are very rare and deserve protection everywhere, whereas in Murmansk Region aapa mires are widely distributed and protecting measures should be focused only on the largest intact areas. Some types of biotopes are absent in particular regions, e.g. coastal meadows are studied everywhere except in Vologda Region, where they are absent. The palsa mires which are found at high altitudes and in the northernmost part of the area were studied only in Murmansk Region.

In this study we try to use all suitable materials to cover the entire territories of the regions. However, areas included in the investigation have been very unevenly studied. Satellite images, cartographic materials, data of forest inventories and data obtained by field studies are more detailed in some areas than in others. These differences are indicated in the descriptions of particular biotopes. The full list of the natural areas of high conservation value used for mapping and analysis in this study is presented in Table 2.1

Dry intact pine forest in Maksimjärvi, (planned zakaznik Spokoyny, Republic of Karelia) with big stone boulders characteristic to Fennoscandian forest. Photo: Jyri Mikkola.

Table 2.1. Biotopes and complexes of biotopes with high conservation value selected and mapped in this study.

+	Biotopes present in the region. Searching for them was conducted according the methods accepted in this study. All HCV areas were mapped, for details see 2.3.
–	Biotopes possibly present in the region. Searching for them was conducted according the methods accepted in this study, but HCV areas were not found, chiefly due to their anthropogenic disturbance
•	Biotopes absent due to natural reasons (the region is located outside their natural distribution area). Searching for them was not conducted
×	Biotopes present in the region but not considered as valuable, being regionally very common (e.g. dry pine-dominated forest in Murmansk Region).
(?)	Insufficient data. Biotopes probably present in the region, but not mapped due to small size and absence of detailed information

Name of biotope / complexes of biotopes	Presence					
	St. Petersburg	Leningrad Region	Vologda Region	Arkhangelsk Region	Republic of Karelia	Murmansk Region
Intact nature landscapes						
Intact forest landscapes	–	–	+	+	+	+
Intact nature massifs						
Intact forest tracts	–	+	+	+	+	+
Intact mire massifs	+	+	+	+	+	+
Particular forest biotopes inside intact forest tracts						
Intact old-growth spruce and spruce-fir forests (excluding hemiboreal forests with nemoral floristic elements)	+	+	+	+	+	+
Intact old-growth pine forests	+	+	+	+	+	+
Intact mountain birch forests adjacent to the tundra zone	•	•	•	•	•	+
Particular mire biotopes inside intact mire massifs						
Ombrotrophic liverwort-lichen-sphagnous, ridge-flark-pool mire complexes (White Sea coasts and eastern part of Baltic Sea coasts)	–	+	•	+	+	+
Ombrotrophic sphagnous ridge-hollow bog complexes (continental)	+	+	–	+	+	+
Ombrotrophic dwarf shrub-lichen-palsa mires (sporadic permafrost)	•	•	•	•	•	+
Ombrotrophic dwarf shrub-sphagnous bogs with pine layer (continental)	–	+	+	+	+	+
Ombrotrophic cottongrass-sphagnous bogs (continental)	–	+	(?)	(?)	+	+
Minerotrophic sedge fens and sedge-grass spring fens (eutrophic)	+	+	+	+	+	+
Minerotrophic sedge- and grass-moss string-flark-pool aapa mire complexes inside the aapa provinces and to the south of the aapa provinces	•	•	+	+	+	+
Minerotrophic sedge-grass-sphagnum, non-structured, oligo-mesotrophic mires	–	+	+	–	+	+
Minerotrophic tree-grass, eutrophic fens	–	+	+	+	+	–

Name of biotope / complexes of biotopes	Presence					
	St. Petersburg	Leningrad Region	Vologda Region	Arkhangelsk Region	Republic of Karelia	Murmansk Region
Particular mire biotopes outside intact mire massifs						
Aapa mires outside the aapa provinces	•	(?)	+	+	+	•
Spring fens (rich herb-moss eutrophic spring fens)	–	+	+	+	+	+
Sloping fens	•	•	•	(?)	(?)	+
Forest tracts with high restoration potential						
Old-growth spruce-dominated forest with high proportion of aspen	–	+	+	+	+	•
Old birch and aspen-dominated mixed forest	–	+	+	+	+	×
Other forest biotopes						
Dry pine-dominated forests confined to sandy dunes, rocks, coasts of large rivers and lakes	+	+	+	+	+	×
Old-growth minimally transformed spruce-fir forests with nemoral elements of ground vegetation in hemiboreal forest zone	•	•	+	+	•	•
Mixed coniferous-broadleaved and broadleaved forests	+	+	+	•	(?)	•
Natural larch-dominated forests	•	•	+	+	•	•
Meadows						
Sea coastal grasslands	–	(?)	•	+	+	+
Tundra biotopes						
Alpine tundras in the forest zone	•	•	•	•	+	+
Biotopes with a prevalence of the abiotic component						
Gorges, ravines, rocky canyons of rivers, cliffs and steep slopes	•	+	+	+	+	+
Coastal biotopes						
Natural floodplain ecosystems (valley complexes), valleys of small rivers and streams, seasonal streams	+	+	+	+	+	+
Intact riversides, flood plain complexes and other natural biotopes at the mouths of rivers	+	+	+	+	+	+
Estuaries	+	+	•	+	+	+
River deltas	+	–	•	+	•	•
Shallow water, littorals and inter-tidal sandy shoals	+	+	•	+	+	+
Aquatic biotopes						
Stratified lakes	•	•	•	•	•	+
Key biotopes						
Salmon spawning sites	+	+	+	+	+	+
Coastal bird colonies.	(?)	(?)	(?)	(?)	(?)	+
Key ornithological territories of the Russian Federation	+	+	+	+	+	+
Habitats of species included in Red Data Book of Russian Federation						
Plants, lichens and fungi	+	+	+	+	+	+
Animals	+	+	+	+	+	+

2.2. Information sources

In this study we use the following sources of information:

- Remote sensing data (middle resolution satellite images)
- Forest inventory data (coloured according to dominant tree species)
- General topographic maps
- Geological and other thematic maps (vegetation, etc.)
- Field inventory data
- Publications, herbariums, etc.

The main information source for this study is satellite images. Other sources, like general maps and forest inventory data are only used as subsidiary materials.

Spectrozonal (i.e. having several spectral channels within visible and infrared diapasons) medium resolution satellite images, taken by the American satellite Landsat Thematic Mapper (TM), Landsat Enhanced Thematic Mapper plus (ETM+), and by the French satellite SPOT-4, representing a spatial resolution of 20–30 meters per pixel, are chiefly used as the primary data source to interpret the species composition of forest stands. They possess spectral channels in the infrared and near infrared ranges. This allows all vegetation types to be detected within the synthesized images. In addition, we use images taken by satellites IRS, Astrer, and Alos. Such images do not evenly cover all studied territory, so they are used where suitable to clarify the contours and characteristics of some types of areas of high conservation value. Both types of images were visualized. The main characteristics of the images used are listed in the Table 2.2.

The image analysis was conducted through expert-based visual interpretation, using geographic information system (GIS) overlays with additional thematic and topographic map layers. For visual interpretation we used the following combination of the infrared channels:

- spectral channels 5-4-3 in the near infrared and visible spectrum ranges for the satellite images Landsat ETM+ and Landsat TM;
- spectral channels 4-1-2 or 4-1-3 in the near infrared and visible spectrum range for the satellite images SPOT-4.

Summer images which allow determining the composition and character of the vegetation were chiefly used for classification of intact forest tracts and biotopes by tree species composition. For the southern part of the study area, we used summer images taken during the period from May to October; for the northern part, summer images taken during the period from mid-June to mid-September. Wintertime satellite images were used to separate forested and unforested areas, to determine exact borders of intact forest tracts and stand density.

Satellite images used in the project were taken between the late 1990s to 2010. For all intact forest landscapes, intact forest tracts and other HCV biotopes in all studied areas, except the Republic of Karelia and the northwestern part of the Murmansk Region, we used the newest satellite images (2007–2010) to reflect the most recent state of the nature areas that are still intact. Fig. 2.2 shows the coverage of the studied territory by the Landsat and SPOT satellite images of different age.

Landsat satellite images taken by the American satellite were obtained from the United States Geological Service (USGS). They are available at the Website (http://glovis.usgs.gov/). We used the most recent orthorectified images treated on the level L1T. For the areas where L1T-images were not available, we used images treated on the level L1G. Satellite images SPOT-4 by the Company "SPOT Image" were obtained by courtesy of the Engineer-Technological Centre "ScanEx" (available at: http://www.scanex.ru).

Additionally, we used high resolution satellite images obtained from the online-services *maps.google.com* and *kosmosnimki.ru.* These images, when available, were used to establish, for example, boundaries of the structural compounds within intact mire massifs, to find the mosaics within forest stands, to clarify the type of the intact mires, etc. In some cases, the results obtained from high-resolution images were extrapolated to similar areas where only medium-resolution images were available.

Forest inventory data of regional level are always needed to support the interpretation of the high resolution images (Maslov 2005). They were used for all studied areas, however in different republics and regions, forest inventory information used for the study was not identical. Most of this information was in the form of generalized forest maps of local offices of the state forest management agency

Table 2.2. The main characteristics of the images used.

Satellite, tool	Spectral channels (bands)	Spectral channel name	wavelength, microns (μ)	Spatial resolution, (m)
Landsat ETM+	1	blue	0.45-0.52	30
	2	green	0.53-0.61	30
	3	red	0.63-0.69	30
	4	near infrared range	0.78-0.90	30
	5	medium infrared range 1	1.55-1.75	30
	6	thermal channel	10.40-12.50	60
	7	medium infrared range 2	2.09-2.35	30
	8	panchromatic	0.52-0.90	15
Landsat TM	1	blue	0.45-0.52	30
	2	green	0.53-0.61	30
	3	red	0.63-0.69	30
	4	near infrared range	0.78-0.90	30
	5	medium infrared range 1	1.55-1.75	30
	6	thermal channel	10.40-12.50	120
	7	medium infrared range 2	2.09-2.35	30
SPOT-4	1	green	0.50-0.59	20
	2	red	0.61-0.68	20
	3	near infrared range	0.78-0.89	20
	4	medium infrared range 1	1.58-1.75	20
	5	panchromatic	0.61-0.68	10
IRS-P6 AWiFS	1	green	0.52-0.59	56
	2	red	0.52-0.59	56
	3	near infrared range	0.77-0.86	56
	4	medium infrared range	1.55-1.70	56
IRS-P6 LISS-3	1	green	0.52-0.59	23,5
	2	red	0.52-0.59	23,5
	3	near infrared range	0.77-0.86	23,5
	4	medium infrared range	1.55-1.70	23,5
EOS Terra Aster	1	green	0.52-0.60	15
	2	red	0.63-0.69	15
	3	near infrared range	0.76-0.86	15
	4	medium infrared range 1	1.600-1.700	30
	5	medium infrared range 2	2.145-2.185	30
	6	medium infrared range 3	2.185-2.225	30
	7	medium infrared range 4	2.235-2.285	30
	8	medium infrared range 5	2.295-2.365	30
	9	medium infrared range 6	2.360-2.430	30
	10	thermal channel 1	8.125-8.475	90
	11	thermal channel 2	8.475-8.825	90
	12	thermal channel 3	8.925-9.275	90
	13	thermal channel 4	10.25-10.95	90
	14	thermal channel 5	10.95-11.65	90
Alos AVNIR-2	1	blue	0.42-0.50	10
	2	green	0.52-0.60	10
	3	red	0.61-0.69	10
	4	near infrared range	0.76-0.89	10

at scales typically between 1:150,000 and 1:300,000. However, for some areas more detailed maps exist though in many cases they were not available to the study.

In **Leningrad Region** we used detailed digital forestry maps (1:25,000). Vector spatial database covered all forest sites aged 100 years and older. In **Vologda Region** we analysed detailed digital forestry maps (1:25,000) that were available for the whole territory except two municipalities, Gryazovets and Shecksna. For the analysis we selected the areas most likely to incorporate forests of high conservation value. We selected all forest sites aged 120 years and older, forest with larch and fir with single trees older than 80 years, forest sites belonging to rare forest types, viz.: swamp-herb, horse-tail, ferny types older than 40 years, forest sites containing elm, ash, oak, linden, and common alder, and all herb-rich forest sites irrespective of age.

In **Arkhangelsk Region** we analyzed detailed digital forestry maps of scale 1: 500,000. This type of map allows determining the predominant tree species (spruce, pine, birch, aspen, larch, willow) and the age category: (1) young, (2) pre-mature and mid-age, (3) mature and over-mature. We chose for the analysis all areas covered with mature and over-mature dark coniferous forests, and also all larch-dominated forest sites.

In **Murmansk Region** and the **Republic of Karelia** we had no detailed digital forestry maps available. We analyzed printed versions of the forestry schemes coloured according to dominant tree species. They were scanned and set in a raster form in the real geographic coordinates on topographic maps of the scale 1:200,000 and more. For **Murmansk Region** we analyzed the most recent forest inventory data of 2006-2008. We used paper forestry schemes coloured by dominant tree species of the scale 1: 50,000. These schemes were not detailed enough to show individual characteristics of the forest sites but allowed us to determine the dominant tree species, age category, quality class, degree of paludification, and other important features.

For the **Republic of Karelia** we had only the older forest inventory data of 1987-1991, mostly on the scale 1: 200,000, the remainder on the scale 1: 250,000. They only allowed determination of dominant tree species and age category dating to about twenty years ago. As additional information for

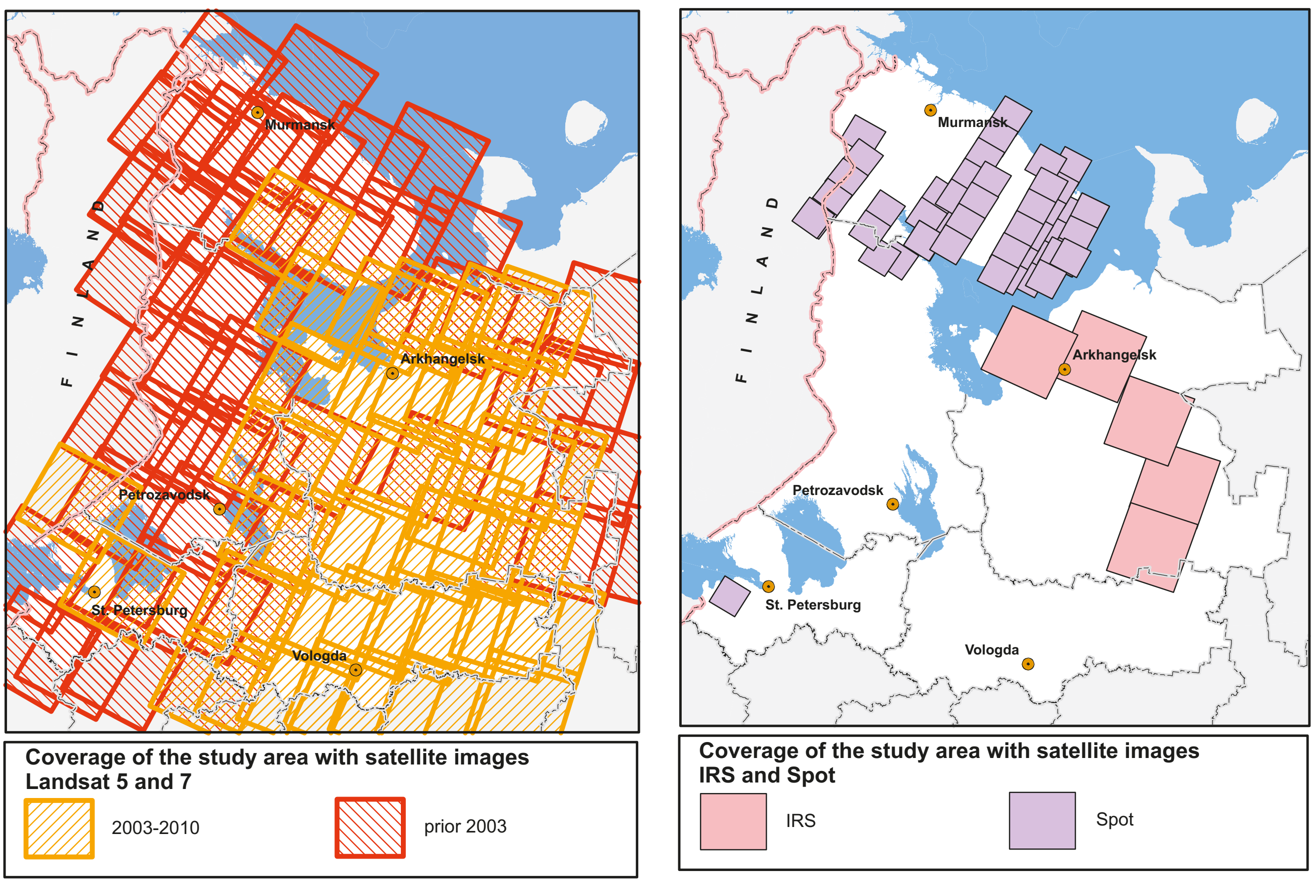

Fig. 2.2. Coverage of the study area with satellite images: left - Landsat, right - IRS and SPOT.

expert visual interpretation of satellite images, we used data of forest inventory in cartographic form also for other study areas, but the Republic of Karelia was exceptional in the sense that there were no forestry maps available in raster and vector formats.

Although the data of the official forest inventory are a very important source in estimating the structure and age of the intact forest tracts, they were used only as auxiliary materials in addition to satellite images, since satellite images reflect the real situation, whereas forest inventories are aimed primarily at estimating timber resources. This leads to several disadvantages which make the results of forest inventories not fully applicable to the goals of our study. These disadvantages can be listed as follows.

– Forest inventories are focused on forest tree species which have economic importance as a source of timber. The main criterion is the standing timber volume, measured in cubic meters. The projective cover of different tree species is not taken into account. This leads to overestimation of the area covered with coniferous forest because even sparse conifers in mixed forest dominated by birch may have larger standing timber volume.

– Rare tree species are usually either under estimated or completely missed in official forest inventories. For example, the presence of broadleaved species in forest stands is noted in the inventories only if they exceed a certain minimum figure. In boreal and even hemiboreal forest zones, broadleaved species often constitute only a slight admixture of the forest stand and their presence may be ignored. As a result, broadleaved tree species may really have wider distribution in an area than is indicated in the forestry schemes. Thus, broadleaved trees are present in particular forest sites if they are indicated in the forestry schemes, but their absence from the forestry schemes may be due to insufficient knowledge. However, even a slight admixture of broadleaved tree species determines high conservation value of the forest, and can serve as a motivation for more detailed inventories aimed at protecting the most valuable forest patches.

– Lack of attention to "minor" indicators, in terms of forest management. In fact, forest inventory data often provide usable information only on tree species composition and age. Other important characteristics, like forest type, moisture conditions, presence of rare plant species, etc., are usually not available. Of course, the quality of forest inventory data depends on the level of forest management in the region, and the performer. In our experience, more or less everywhere we can confidently rely on the average age (unless it is a very old forest where the age structure in forest inventories can often be inaccurate) and on the indication of the main forest-forming tree species, though even their quantitative ratio is often determined only very approximately.

– The quality of the forest inventory data is uneven, from region to region and even from one forestry unit to the next. We often met difficulties in comparing adjacent forest areas under the management of different forest companies. Generally, in regions with high-quality forest management, such as the Leningrad Region, the reliability of the data tended to be higher than in neighboring areas. However, the same criteria could not be applied to this data as were used throughout the study because of the lower quality of forest inventory data comparable with other republics and regions.

– Although the contours of the forest ecosites in the modern forestry schemes are based on the materials obtained with remote sensing (previously using aerial photography, in recent years mainly satellite imagery), the interpretation of these materials is not always objective. The classification of vegetation is not totally reliable and planning of conservation measures cannot be based exclusively on these materials.

General topographic maps were an additional source of information. We used maps of scale 1:200,000 for the whole research area. These maps have been used as a source of two main types of information: the relief, and the basic elements of infrastructure, such as towns and villages, industrial facilities and permanent transportation infrastructure. Unfortunately, vector digital maps in GIS format were not available for the whole territory. For those parts of the territory where vector digital maps in GIS format were not available, we used paper maps in standard sheets. They have been scanned and linked to real geographic coordinates using the coordinates indicated at the corner of every sheet.

Details of the relief are of critical importance to identify a number of valuable natural areas whose very conservation value is a result of the peculiarities of the terrain. Also, detailed knowledge of the relief obtained from topographic maps greatly assists in the interpretation of satellite images. Unfortunately, maps of the scale 1: 200,000 do not always provide descriptions of the terrain detailed enough for our goals due to low accuracy in the representation of certain objects. General topographic maps were therefore used only for mapping some very basic elements of infrastructure and for borders of woodless bogs and highlands within intact forest landscapes.

The basic goals of the mapping of basic elements of man-made infrastructure (especially roads) were to exclude industrially disturbed and fragmented areas from further analysis, and to divide intact forest landscapes into discrete parts, separated from each other by elements of industrial infrastructure. Unfortunately, we must recognize that on most available topographic maps this information was out of date, with industrial infrastructure (e.g. borders of towns and villages, quarries, road network, etc.) reflecting the situation at the beginning of the 1990s or even in the mid-1980s. To update this information we used satellite images. Comparison of recent satellite images with the outdated information indicated on the topographic maps has allowed estimations of the changes caused by human impact during the last two decades and, in some cases, made possible tracing of the recovery process of ecosystems after anthropogenic disturbances.

Orthorectified Landsat satellite images were the basic source for geo-referencing of forest inventory data because these images give much better quality than topographic maps of scale 1:200,000. However, in some cases, we used also topographic maps for geo-referencing of forest inventory data in raster format. For instance, clearings and other traces of forest management, which are very useful landmarks in combining images from different sources, are often not visible on medium-resolution images but are mostly marked on topographic maps. The maps being twenty and more years old was here rather an advantage, because the maps include all clearings, also those which have become overgrown during the last two decades.

In addition, topographic maps include important information on the types of soil and on the density of forest cover in certain areas. Generally, this data was not used because its reliability is doubtful. In some cases, however, we took it into consideration as an indirect indication which needs confirmation, e.g. by field inventories.

Thematic maps were the third major source of information. We used all suitable geological maps (above all, maps of Quaternary and Pre-Quaternary deposits), which served as a source of information about the distribution of particular kinds of geological bedrock (e.g. carbonate rocks), and allowed some assumptions about the soil type. In addition, we used all suitable maps of vegetation, ranging from the "Map of Vegetation in the European Part of the USSR (1979)", and "Forests of the USSR (1990)" to local and regional forest maps highlighting dominant plant species. We also used all suitable geobotanical and landscape maps of the studied territory. The availability of these maps was especially valuable for those areas lacking data from the field inventory. However, all the thematic maps were small scale (1:500 000 - 1:2,500,000), allowing only a general view of the territory.

More detailed thematic maps, which have a great value in our study, were available only for certain regions and for certain types of biotopes. For example, in the Republic of Karelia, the regional experts in mire biotopes have used large-scale (1: 25,000 and 1: 50,000) maps in the interpretation of mire vegetation from aerial photographs. Fig. 2.3 shows as an example a fragment of a map sheet of the Rugozero forestry unit with mires color coded.

These printed thematic maps show the borders of mires, the network of inventory mapping squares as they were in the 1950s-1960s, and the hydrographic network. Within the contours of mire complexes, all types of mire sites (or facies) are color coded. The identification of mire vegetation and hydrological peculiarities within every facies has been made based on the aerial photographs. Maps contain thematic information about the type of mire massifs, the morphology of mire basins (I-XI) and the phase of development of the mire, viz.: oligotrophic [O], mesotrophic [M] and eutrophic [E] phases according to the classification proposed by E. A. Galkina (Galkina 1959). The legend and symbols follow Galkina (1959, 1964). These paper maps have been converted into a digital raster format, suitable for computer processing.

We also used general maps of mire vegetation and geobotanical maps which cover the whole territories of the Murmansk Region and the Republic of Karelia. The geobotanical map of the Murmansk Region, scale 1:1,000,000 (Chernov 1953) is available only as a printed cartographic source. The map of mire vegetation of the Karelian ASSR (1968) in the scale of 1:600,000 is currently being converted into a digital format (Yurkovskaya & Elina 2009).

Unfortunately, maps of mire vegetation and geobotanical maps were available only for Murmansk Region and the Republic of Karelia. For all other regions of northwest Russia, we used materials of

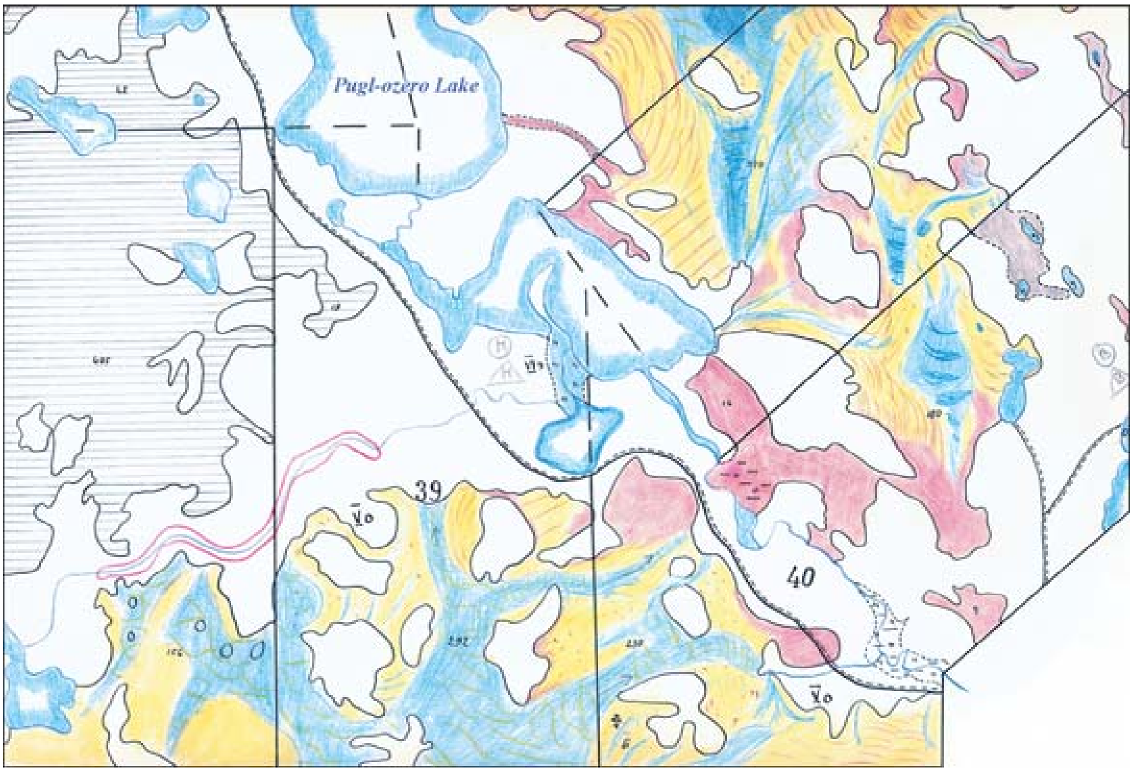

Fig. 2.3. A fragment of the thematic map of the Rugozero forestry unit with the interpretation of mire vegetation from aerial image.

the inventory of peat resources (e.g. Peat Resources 1955, Peat resources 1970). We also used published data on mire vegetation, particularly data on the distribution of mire biotopes with high conservation value (Description on vegetation…1992) with subsequent verification during field investigations.

Expert visual interpretation was the primary method of interpreting satellite images. The purpose of the interpretation was to identify areas of high conservation value. Interpretation was carried out in a GIS ESRI ArcMap 9.3. environment with the simultaneous use of satellite images, results of cartographic analysis, thematic maps and field data collection in key areas. Landsat satellite images treated on the L1T-level usually have sufficient detail for detecting intact forest landscapes. Landsat satellite images treated on the L1G-level, and SPOT satellite images often demanded additional georeferencing, done with the help of the orthorectified Landsat satellite images treated on the L1T-level. The georeferencing of scanned maps was done using ERDAS Imagine GIS or the ScanEx Image Processor.

Expert visual interpretation of the Landsat satellite images (see 2.3.2 below) was carried out in a ScanEx NeRIS program (version 2.10) and with use of the module Thematic Pro for the ScanEx Image Processor. Spectral profiles for all vegetation classes on basis of field data collection in key areas were made using ERDAS Imagine GIS.

Fig. 2.4. A fragment of the map of mire vegetation of the Karelian ASSR (the Louhi region).

2.3. Methodology of identification and mapping /detecting of high conservation value areas

2.3.1. General approach

This work is an attempt to identify and map all areas of high conservation value throughout the territory of northwest Russia, whether currently inside or outside existing protected areas. To achieve this we use the principles listed above.

- Satellite images were the main information source for this study. Other sources, like general maps and forest inventory data were only used as subsidiary materials. For instance, there are intact forest tracts which belong to rare forest site types. Areas of this kind were difficult to find using satellite images only. They were identified using data of the forest inventory and field data collected in these areas. Their boundaries were delineated according to the borders of the forest ecosites that were indicated in the forestry maps, or by using co-ordinates obtained with GPS-navigators during field investigations.

- Intact forest landscapes based on available maps and medium-resolution satellite images were identified first as entire areas without division into particular biotopes. This approach was used to exclude obviously disturbed areas from further consideration. Then, particular biotopes were delineated within the whole intact area on the basis of detailed interpretation of satellite images.

- Intact forest tracts were identified only where their areas exceeded the threshold values indicated in Table 2.3 and Table 2.6. This approach was applied to both forest and mire massifs, and the minimum size required to allow their consideration as separate intact natural landscape varied, depending on the region. The minimum size of forest tracts with high restoration potential (mixed birch-aspen and spruce-aspen dominated forests) was 100 hectares, throughout all the regions studied.

Biotopes of high conservation value were identified within **intact forest tracts** and also outside them. Minimum sizes of particular biotopes of high conservation value, if they were delineated outside intact forest tracts, are indicated in Table 2.4. Sites deserving inclusion in intact forest tracts, and what areas should be excluded, were decided as follows:

- Generally, we excluded from the intact forest tracts all areas affected by rather strong and relatively recent human impact. Types of infrastructure considered as anthropogenic disturbances within intact forest tracts are listed in Table 2.5. However, the buffer zones of these different types of infrastructure have not been drafted and not excluded from the intact forest tracts.
- Non-forest ecosystems, if they were considered to be intact, were included among intact forest tracts.
- Sites having undergone transformation caused by humans, as well as sites with no special conservation value, were included among intact forest tracts if their area does not exceed 5% of the total area of the intact forest tract.
- Rivers, lakes and other water bodies less than 2 km wide, were not considered as borders between intact forest tracts, but were included in the same intact forest tract.

Table 2.3. Minimum sizes of intact forest tracts mapped in this study.

Region	Minimum area, ha
Murmansk Region	1,000
Republic of Karelia. Northern part (Louhi municipality, Kostomuksha municipality, Kalevala municipality, Kemi municipality, Muezerka municipality, Belomorsk municipality, Segezha municipality, and the northern part of the Medvezhyegorsk municipality)	1,000
Republic of Karelia. Middle part (Kondopoga municipality, the southern part of the Medvezhyegorsk municipality and the northern parts of the Suojärvi and Pudozh municipalities)	500
Republic of Karelia. Southern part (Prionezhsky municipality, Pryazha municipality, Olonets municipality, Pitkäranta municipality, Sortavala municipality, Lahdenpohja municipality, and the southern parts of the Suojärvi and Pudozh municipalities)	100
Arkhangelsk Region, northern part.	2,000
Arkhangelsk Region, central and southern parts	500
Leningrad Region	100
Vologda Region	100

Table 2.4. Minimum sizes of particular types of biotopes with high conservation value.

Types of biotopes with high conservation value	Minimum area, ha
Spruce-dominated forest (old-growth)	Mapped only inside intact forest tracts (see Table 2.3)
Pine-dominated forest (old-growth)	Mapped only inside intact forest tracts (see Table 2.3)
Mountain birch forest in the tundra zone	Mapped only inside intact forest tracts (see Table 2.3)
Dry pine forest (on dunes and rocks)	10
Old-growth, minimally transformed spruce-fir forests in hemiboreal zone	1-2
Broadleaved and mixed coniferous-broadleaved forests	1-2
Natural larch-dominated forests	Vologda Region – less than 1 ha; Arkhangelsk Region – 30 ha
Mire biotopes inside intact mire massifs	See Table 2.6
Spring fens and sloping fens	Without restrictions on minimum size
Aapa mires outside aapa-mire provinces	See Table 2.6
Coastal meadows	0,5
Alpine tundras in forest zone	10
Estuaries	1-2
River deltas	1000
Coastal biotopes, littorals, sand banks	1-2
Natural floodplain ecosystems (valley complexes), valleys of small brooks and streams, seasonal streams	Without restrictions on minimum size, starting from 50 m wide

Table 2.5. Types of infrastructure excluded from (left column), and included in (right column) intact forest tracts.

Types of infrastructure excluded from the borders of intact forest tracts	Types of infrastructure included in intact forest tracts
• Railways with buffer zones (except narrow-gauge railways); • paved road with a right of way; • improved unpaved roads; • corridors of pipelines; • industrial areas; • all settlements; • mines, quarries and other sites of mineral extraction on exposed mineral soils; • arable land; • meadows formed on abandoned arable lands; • clusters of recent (last 50 years) clearcuts; • recently burned areas, if adjacent to infrastructure or associated buffer zones, as well as repeated old burns; • secondary birch and aspen forests with ratio of conifers not more than 10-20%; • forests used for resin extraction.	• Narrow-gauge railways (all now abandoned or dismantled; no operating narrow-gauge railways were found adjacent to intact forest tracts); • land management and forest roads, power lines and other cleared areas; • islands, if the distance between them is less than 2 km; • water bodies less than 2 km in width; • natural meadows (excluding abandoned arable land); • drainage ditches in peat bogs where the drainage has not lead to a complete transformation of mire ecosystems; • areas of selective cutting; • old-growth aspen and birch forests, particularly those including dark conifers.

2.3.2. Methodology of semi-automatic identification of different types of vegetation

Source: multispectral medium-resolution satellite images, Landsat ETM+ and Landsat TM. In most cases we used the most recent (2007–2009) images with the data processing level L1T. For some areas we used images of processing level L1G taken earlier (but none earlier than 1999) because of lack of better data at the time of analysis.

Expert visual interpretation and classification of biotopes present in the Landsat satellite images was carried out in a ScanEx NeRIS Image Processor (version 2.10) by the method of training neural networks. We used the Kohonen neural network (Kohonen self-organizing maps: Kohonen 1982, Kohonen 1990, Fausett 1994, Haykin 1994, Patterson 1996). At the initial stage of classification, spectral profiles for each class of vegetation type and wetland were constructed with the help of the ERDAS Imagine GIS program, supported by adequate verification by the regional experts. Spectral profiles were used for determination of the weight of each spectral channel for further classification. The most notable differences between the vegetation and mineral surfaces were clearly observed in all channels, except for channel 4 (near infrared). Various types of vegetation were well-differentiated in channel 4 (near infrared, 810–1000 nm) and channel 5 (middle infrared, 1550–1750 nm).

To avoid difficulties in the separation of certain types of wetlands from types of mire vegetation which have similar spectral characteristics, we used a method called "mask forest/non-forest", created by researchers from the University of South Dakota (Potapov et al. 2011).

Arable lands and the large-scale infrastructure objects present in the satellite images were identified manually. All these territories were excluded from further analysis.

As an additional layer we used the analytical result of changes (change detection), obtained by comparison of multitemporal Landsat TM and Landsat ETM + satellite images obtained during the course of 1985-2002. This has allowed identifying areas in which there have been significant changes in forest cover. The newer images made it possible to detect the most recent disturbances, and the older images allowed us to detect older disturbances whose traces have become less evident with time. These data were used for the preparation of maps of forests in central and northern areas of the European part of Russia (Yaroshenko et al. 2008) and are available from the website http://forestforum.ru/info/gis/vectors.zip.

As a result of our own classification and use of available Web-sources (Fig. 2.5), we have prepared a map of the main types of vegetation in northwest Russia (Fig. 2.6). The map includes the following classes, which do not fully correspond with the generally accepted classifications of vegetation. Nevertheless, they can be used for the primary analysis of vegetation cover for those areas where detailed geobotanical maps are absent:

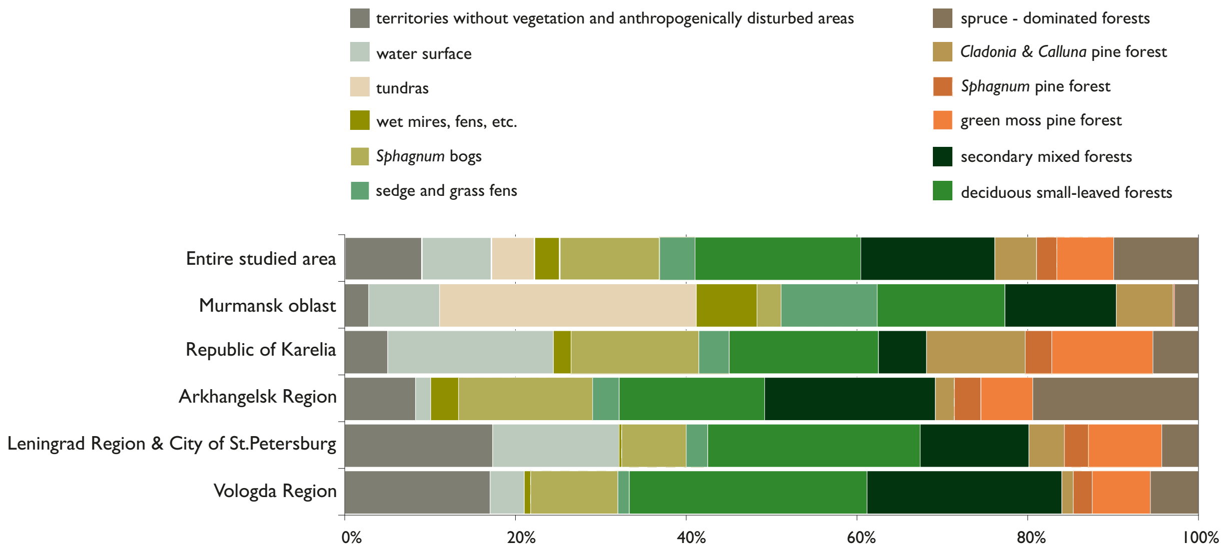

Fig. 2.5. Distribution of vegetation types in the studied regions of northwest Russia, after semi-automatic interpretation of Landsat satellite images.

1. Forests dominated by dark-conifer species (spruce and fir)
2. Green moss pine forests (*Pleurozium – Hylocomium* types)
3. Dry pine forests (*Cladonia, Calluna and Empetrum* types)
4. Sphagnum pine forests (*Sphagnum* type)
5. Deciduous small-leaved forests
6. Secondary mixed forests (gradually recovering former coniferous type)
7. Sphagnum bogs
8. Sedge and grass mires, sedge and grass fens
9. Wet fens
10. Cutting areas
11. Burned areas
12. Windfalls
13. Water
14. Tundra
15. Areas without vegetation

In order to minimize possible errors, classes 10, 11, 12 and 15 above are combined into one class – "territories without vegetation and anthropogenically disturbed areas."

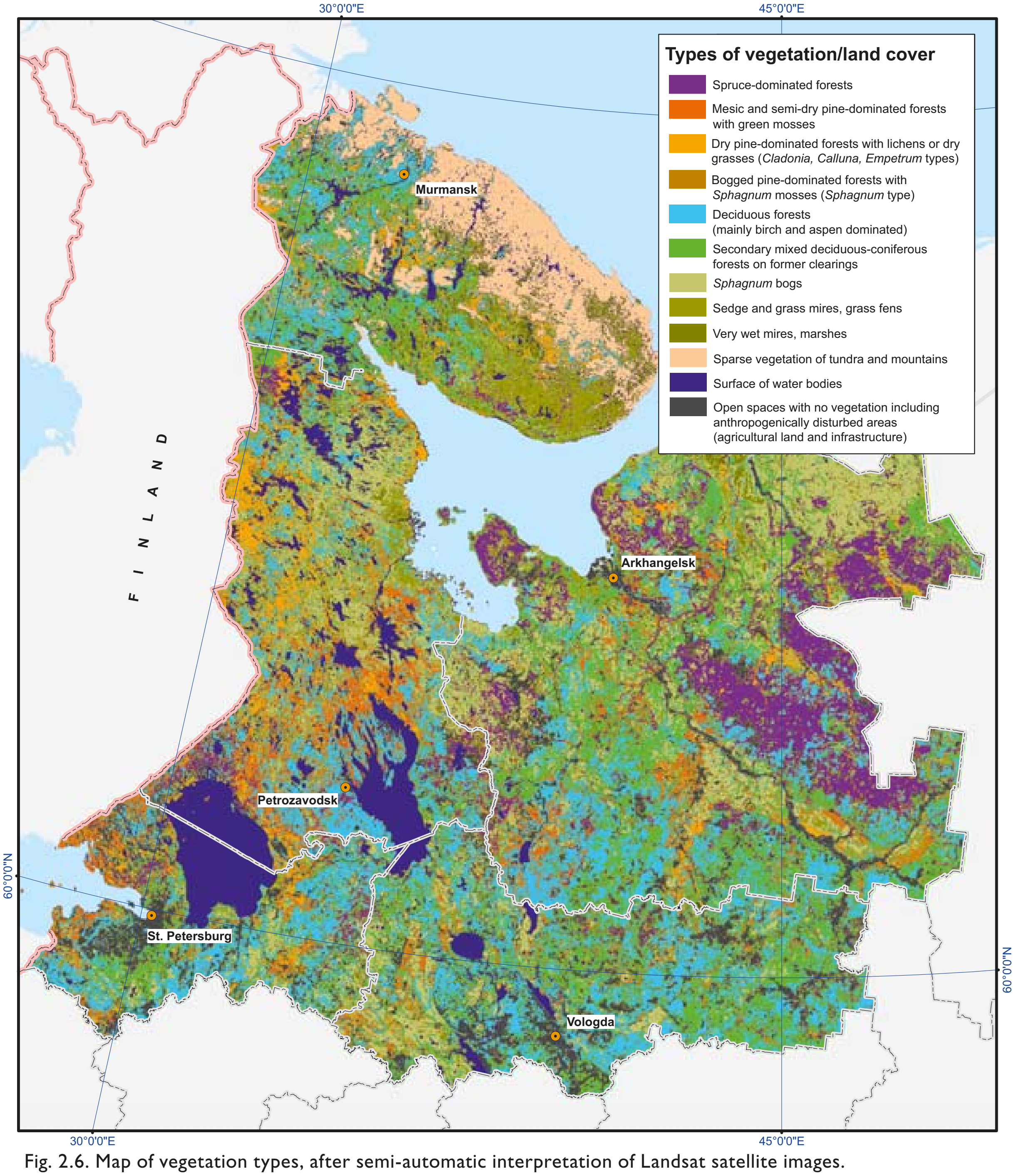

Fig. 2.6. Map of vegetation types, after semi-automatic interpretation of Landsat satellite images.

2.3.3. Intact forest landscapes

To identify intact forest landscapes we followed methods described in detail in the two publications:

- Yaroshenko A, Yu., Potapov P.V. & Turubanova S.A. 2001. The Last Intact Forest Landscapes of Northern European Russia. Moscow: Greenpeace Russia. 75 pp. (http://forest.ru/rus/publications/north/).
- Aksenov D.E., Dobrynin D.V., Dubinin M.Yu., Egorov A.V., Isaev A.S., Karpachevsky M.L., Laestadius, L., Potapov, P.V., Purekhovsky, A.Z., Turubanova S.A. & Yaroshenko A. Yu. 2002. Atlas of the intact forest landscapes of Russia. Global Forest Watch Russia. Moscow. 185 pp. (http://forest.ru/rus/publications/intact/).

In this study we have checked and improved borders of the formerly identified intact forest landscapes (e.g. Yaroshenko et al. 2001, 2008, Aksenov et al. 2002). As the primary data source we used vector layer of the borders of intact forest landscapes as of 2008.

We have compared the old borders of intact forest landscapes with more recent ones obtained with the help of the Landsat TM and Landsat ETM+ satellite images taken in 2009–2010. For two small areas we used Landsat TM satellite images which were taken in 2007, because of lack of better data at the time of analysis.

The analysis was based on a buffering approach: buffers were defined around roads, pipelines, power lines and settlements, and the buffer zone subsequently eliminated from the area of study. We used buffer zones indicated by Yaroshenko et al. (2001) and Aksenov et al. (2002). The numerical values of some parameters of methods referred to in the two above-mentioned publications are slightly different. Some of the criteria, in particular buffers around forest roads, were taken only from Yaroshenko et al. (2001). We did not rebuild the buffers and the boundaries of the intact forest landscapes with the exception of cases where new forest roads have been constructed after 2001. For them we built 500 m buffers around every forest road.

We also analyzed treeless land caused by intense air pollution near metallurgical plants in the Murmansk Region as newly appeared anthropogenic infrastructure. Areas with visually identifiable changes in vegetation from satellite images were excluded from the boundaries of the formerly identified intact forest landscapes.

2.3.4. Old-growth minimally transformed spruce and spruce-fir forests (except hemiboreal and southern boreal forests with nemoral elements)

Forest landscapes and forest tracts were defined as old-growth and minimally transformed if they have long been practically unaffected by human activity and where at least two of the following criteria are fulfilled. First, the forest should be "old-growth" in the sense that the average tree age of predominant species is relatively high and the tree age and the spatial distribution of trees are not too uniform. Such structure of forest ecosystem reflects natural formation without any management. Second, the area of forest should be large enough to maintain natural succession (minimum areas differed depending on region, see Tables 2.3 and 2.4), and the forest landscape or forest tract should not be severely fragmented. If the forest landscape or forest tract was adjacent to other HCV areas, or created mosaics with them, we assessed these circumstances as additional advantages. In fact, we included in this group all old-growth spruce and spruce-fir forests if they were large enough and were not fragmented.

Dark coniferous spruce-dominated forests (as well as mixed forests with large proportion of spruce) are easily defined by the interpretation of the spectrozonal satellite images, both by expert visual interpretation and by semi-automatic methods. We used the 5-4-3 band combination for the Landsat satellite images and 4-1-2 band combination for the SPOT satellite images. Forests with a large proportion of spruce generally have dark tones (markedly darker than pine-dominated forests) with domination of dark blue, dark purple and dark brown colors. They also account for missing or much smaller proportion of inclusions of the pinkish purple tone which is often found in pine forests (Fig. 2.7). Such pinkish purple inclusions, as a rule, are the result of the signal reflected from the ground cover and passing through the sparse canopy. A typical spectral portrait of a forest site dominated by spruce, built using ERDAS Imagine, is shown in Fig. 2.8. Both old-growth spruce and fir-dominated sites (dark color) and adjacent pine-dominated sites (pinkish purple) have fairly clear boundaries.

To determine the real age of spruce-dominated forests, especially their successional age, using satellite images only is quite difficult. However, this

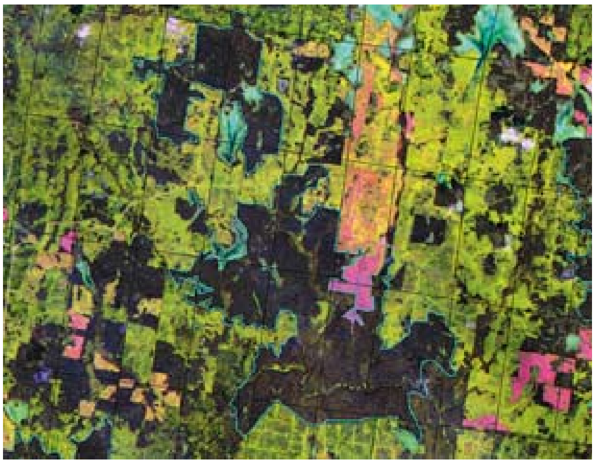

Fig. 2.7. Allocation of old-growth spruce and fir-dominated forests tracts by satellite images Landsat ETM +, combination of bands 5-4-3, Arkhangelsk Region.

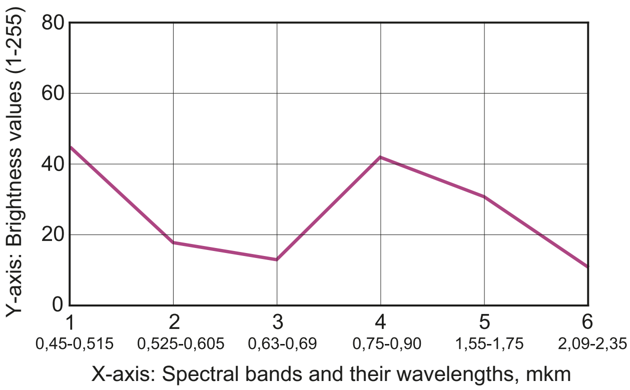

Fig. 2.8. A typical spectral portrait of a plot of old-growth spruce-dominated forest from satellite images Landsat TM / ETM +.

method allows making some assumptions. First of all, in the whole study area, we found only a few examples of successful artificial regeneration of spruce in sites subjected to clear cutting, forest fires, or on abandoned agricultural land. Natural reforestation of sites formerly covered with spruce forest almost always goes through a succession of tree species. Usually deciduous tree species grow in the places formerly covered by spruce, i.e. coniferous forest are replaced by young stands consisting mainly of birch, alder, aspen or other deciduous trees. Pine can be a pioneer tree especially on dry sites, those with poor soils, or on sites of frequent fires. Young spruce regenerate only under a canopy of deciduous trees or pine, gradually replacing them after 70-80 years in the southern part of the study area, 100-120 years in the northern part. Thus, the predominance of spruce in the upper canopy layer indicates a fairly long period of natural succession. However, this is not always strong evidence of the high conservation value of a forest stand, especially in the southern part of the study area.

In some cases, the oldest and largest unfragmented landscapes and tracts of spruce-dominated forests with a number of structural features visible on satellite images were classified as HCV areas without additional study of forest inventory data and field inventories. However, in most cases, we tried to obtain additional information concerning forest age, structure and species composition from forest inventory data, together with such characteristics as presence of significant amounts of wood in different stages of decay, findings of red-listed species or other species which demand continuity in the forest massif, etc., obtained during field surveys.

We tried to identify and delineate the boundaries of all old-growth forests areas dominated by spruce (intact forest landscapes) and old-growth spruce-dominated tracts located outside them. In some cases, the contours of intact spruce-dominated forests contain a large admixture of pine forests. We did not build buffer zones around man-made objects. Generally, these principles were applied to the whole study area, but there were slight differences between the regions.

In **Murmansk Region** we mapped almost all forest sites which were considered old-growth and spruce-dominated according to data obtained with satellite images. Basically, we used the Landsat and SPOT satellite images. Forest inventory data were less used, for only a few areas. Since the intensive development of the region, with associated disturbances of the intact forests (e.g. clearcuts, fires, road construction and mining), started relatively recently (1930s), we believe that all coniferous forests that still exist in the territory of Murmansk Region were formed before this period of human impact and can, therefore, be considered as intact.

Since the selection of intact forest landscapes and intact tracts of coniferous (mostly spruce-dominated) forests in Murmansk Region was carried out almost solely on the basis of their size and fragmentation scale (see 2.3.1.above), their conservation value may differ because of wide distribution of such low-intensity disturbances as local forest fires, selective logging, and grazing by reindeer. Based on our experience of field work in Murmansk Region, direct field survey is always necessary for the exact estimation of the conservation value of a forest area or forest massif. Unfortunately, field survey data for all sites of potentially old-growth forest was not available.

Selection of intact forest sites was carried out primarily by visual interpretation with manual drawing of their boundaries. In this stage, spruce-dominated forest sites were often combined into the mutual contour with pine-dominated old-growth forests, mires, and mountain areas. Later they were separated using automatic classification systems. The only exception is the largest intact forest landscape, which occupies a large territory in the eastern part of the Murmansk Region (almost the entire southern half of the Kola Peninsula). Forest areas there are often interspersed in a mutual complex contour together with intact wetland ecosystems. We have not delimited them from each other but mapped as an entire contour.

In all other cases we delineated rather small areas of spruce forests, starting from 2-3 ha as the smallest. Then we combined them with intact mires and other types of natural biotopes in intact forest tracts according to the principles described above (2.3.1.). The minimum size of the intact forest tract for the Murmansk Region was 1000 ha (see Table 2.3).

For the **Republic of Karelia** we used generalized forestry schemes, about 20-25 years old, colored according to the dominant species (see 2.2 above). Based on that, we determined the presence of intact forest tracts and their dominant tree species (spruce or pine). Then we estimated their current status, namely: boundaries, area, degree of fragmentation, degree of disturbance, tree species composition, using data obtained with satellite images. This was performed by expert visual interpretation of satellite images and using scanned forestry schemes as an additional raster layer in GIS-system.

Old-growth spruce forests in Karelia were allocated in the intact forest tracts together with the other types of old-growth forests and other intact natural areas, using the methods previously described (2.3.1. above). The size and fragmentation of the forest tracts were evaluated simultaneously with the delineation of their borders, without further filtering by size. Isolation of smaller areas and fragments that do not meet the criteria of the intact forest tracts within them, has not been conducted. The exact delineation of the sites of old-growth spruce forests was done in the following stage, using semi-automatic classification of the Landsat satellite images (see 2.3.2 above).

In **Arkhangelsk Region** we tried first to find possible old-growth intact forest landscapes and tracts using the forestry scheme of Arkhangelsk Region (scale 1:500,000). Further verification of their boundaries was carried out by expert visual interpretation of the Landsat satellite images. In this stage we used satellite images taken in 1999-2003. Later, the results were corrected using newer satellite images Landsat and IRS-P6, taken in 2007-2009, and satellite images available from the website http://kosmosnimki.ru. As a result of recent loggings in many parts of the intact forest tracts selected for mapping, several changes were made after the comparison of older and newer images.

The boundaries of the intact forest tracts were drawn using the methods described (see 2.3.1. above). Non-forest natural HCV areas are presented within the intact forest tracts only in minor fractions. Selected intact forest tracts are predominantly represented by old-growth spruce-dominated forests, other types of old-growth forests were found relatively seldom. However, at the first stage of the visual interpretation of the satellite images, we did not separate old-growth spruce- and pine-dominated forest. Within large intact forest landscapes, selections of old-growth forests by predominant tree species were done using semi-automatic classification of the Landsat satellite images. Within intact forest tracts, this selection was done by field inventories in some instances and by further analysis of the information obtained with satellite images.

In **Vologda Region,** selection of the intact forest landscapes and intact natural massifs was performed by expert visual interpretation of the Landsat and the SPOT satellite images. To verify the age of the forest sites and the scale of disturbance we used forest inventory data and the regional forest management database for the particular sites which were selected during field surveys in 2008, 2009 and 2010. This work was conducted by the regional expert group in cooperation with the partnership Transparent World, Moscow. Vologda Region is characterized by very high anthropogenic disturbance of most forests which still exist there. For this reason, even small forest areas with remaining old-growth structure are of potential interest. Therefore, we have selected from the satellite images all forest sites exceeding 1-2 ha for further study. These plots were selected either inside intact forest tracts, together with old-growth forest patches of other types and other intact natural objects, or separately (e.g. small patches of spruce forest surrounded by agricultural land, drained mires, anthropogenic infrastructure, etc.) Of these, we selected those forest tracts which met the HCV criteria described above (see 2.3.1.)

In Leningrad Region spruce-dominated forests cover quite large areas. However, in contrast with all other regions included in this study, most of these forests are anthropogenically disturbed to such an extent that they no longer have significant value in terms of nature conservation. Therefore, in order to define intact forest tracts in Leningrad Region, we have to rely on the forest inventory data and data collected by members of the Regional Working Group during the years of field work, to a greater extent than in other regions. Data of the most recent forest inventory and the State forest management database were available for almost the entire forest covered land in Leningrad Region. From this material we selected all mature and over-mature forests stands (aged 80 years and older), which formed more or less continuous forest tracts to meet the given (2.3.1) dimensional criteria.

Selection of intact forest tracts was performed on the basis of forest inventory data, in addition to which spruce-dominated forest tracts were selected independently using the Landsat satellite images. As in Vologda Region, we selected for further study all spruce-dominated forest sites of 1-2 ha and more, either inside intact forest tracts together with old-growth forest patches of other types and other intact natural objects, or as exclusively forest sites. After that, we verified the data obtained from satellite images by combining them with those extracted from forest management databases (where such data were available) and from forest inventory data. In cases where data were conflicting, verification was on the basis of data collected during field inventories. In 2010 we conducted a field survey on some sites that required additional study. Finally, from the selected forest tracts, we selected those which met the HCV criteria (see 2.3.1).

2.3.5. Old-growth minimally transformed pine-dominated forests

As with the spruce-dominated forests, for pine forests we considered as potential HCV areas only those forest landscapes or forest tracts that were(1) old-growth, at the age over 70-80 years old in the southern part of the study area, and over 100-120 years old in the northern part, and (2) met the criteria of minimum size and minimal scale of fragmentation (see Tables 2.3 and 2.4). If they were adjacent to other HCV areas, it was considered an advantage.

Pine-dominated forests, in contrast to spruce-dominated forests, are more difficult to map, either using interpretation of satellite images, or on the basis of forest inventory data. Generally, on satellite images (band combination 5-4-3 for the Landsat or 4-1-2 for the SPOT) pine forests look darker than mixed or deciduous forests. The main color range of pine forests is brownish, often brown-purple, purple or dark green. There is, however, a smaller proportion of yellow and light green tones. Thus, pine forests have slightly lighter colors than spruce forests, which are always dark in the satellite images. Therefore, in some cases, they might fuse with mixed forests in their surroundings, which have shades of yellow, green, light brown, pink, light blue-violet and other similar colors. Fig. 2.9 shows a typical spectral portrait of old-grown pine forest, built using the ERDAS Imagine system.

Spectral portraits of pine forests, due to their relatively low density in comparison to spruce forests, are more heavily dependent on the type of ground vegetation and growth conditions than on tree age. During visual interpretation, we divided pine-dominated forests into two clearly distinct groups:

- Paludified pine forest of *Sphagnum* type, mesic and sub-xeric pine forests with green mosses in the ground cover in satellite images (band combination 5-4-3) usually have dark green color, sometimes with gray, crimson, pink and yellow shades. They are clearly darker than young pine regrowths, secondary broadleaved and mixed forests, but lighter than spruce-dominated forests.
- Pine forests with lichens in the ground cover (*Cladonia* type group) in satellite images (band combination 5-4-3) usually have pink or crimson color of varying intensity.

Pine, in contrast to spruce, recoveres clearings without a long period under a deciduous canopy, and quickly forms the first canopy level. For this reason, spectral portraits of relatively young pine stands may not differ significantly from those of old-growth. This creates difficulties in selection of old-growth forest tracts using satellite images solely. We always analyzed satellite images in combination with forest inventory and field survey

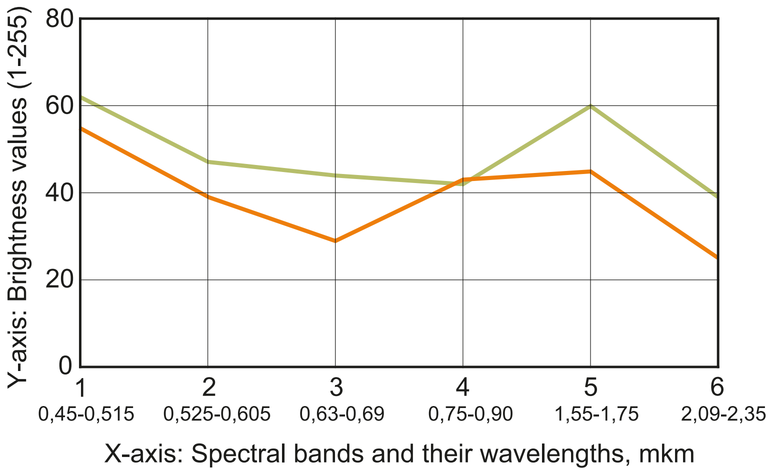

Fig. 2.9. A typical spectral portrait of a pine forest stand in satellite images Landsat TM / ETM+. The green line is for pine forests of *Sphagnum*, and green mosses types; the orange line is for pine forests of *Cladonia* type .

data, where they existed. This method was used for the Republic of Karelia and for some parts of the Vologda Region. In the estimation of tree age, we relied on information from the forest inventory data wherever it was available. We selected chiefly pine-dominated stands aged 150 years or more. Pine forests averaging 190 years or more were of most importance. In areas where we lacked exact data of forest age, we selected for further analysis all the sites that were indicated on the forestry schemes as "mature and over-mature forests".

Dealing with forest inventory materials, we were facing with the fact that the average age of the pine forests specified both in databases and on forestry schemes does not always correlate with the presence of old trees, and does not always reflect old-growth type of stand structure. For example, we repeatedly encountered situations where pine-dominated forest stands which were indicated as "mature and pre-mature" (sometimes even 60 years old) in the forest inventory, in fact included numerous very old pine trees. Such stands are therefore of very uneven age and of substantial conservation value as examples of forest formed by natural succession. From this, it followed that the requirement for a mention of a given site as “old” in the forest inventory could not be applied rigorously as a criterion. It was enough that high age was specified for a small fraction of the forest site. Also, if a particular fraction of the forest site looked potentially old-growth based on its spectral and textural features in the satellite image (i.e. the same as one of the adjacent sections indicated as old in forest management data), we tried to find field survey data or, if they were not available, in some cases considered this forest fraction as old-growth. We applied such extrapolation only for spatially close sites of the same or similar geomorphologic elements (e.g. along a river valley).

In **Murmansk Region**, we considered as old-growth all pine forests with no traces of human impact visible on satellite images, and indicated as old enough in forest inventory data. As mentioned above, wide-scale industrial development of the region started only in the 1930s, and pine forests formed in former clearcuts, abandoned mining areas, agricultural lands, etc., are usually relatively young. Typically, they could be discriminated from the old-growth forests on satellite images, even without the study of forest inventory data. The "geometric" boundaries of such forest stands, as well as their lower density (or, conversely, some plots could be much denser) are typical signs of secondary pine forests, visible in satellite images.

Intact forest tracts were selected primarily by visual interpretation of satellite images. Small areas of pine forests were discarded in the first stage. We selected only those sites, either within bigger forest areas or situated apart from them, which covered areas greater than the minimum of 1000 ha (see Table 2.3). In many cases, pine forest stands were combined into the entire intact forest landscape with old-growth spruce forests and with intact mires. Later, they were either left in the entire intact forest landscape, or were divided into intact forest and mire massifs according to the automatic classification of satellite images. In the largest intact forest landscape, located in the eastern part of Murmansk Region, forest tracts are often interspersed in a vast continuous area of wetlands, and they were not selected.

In the **Republic of Karelia,** pine-dominated forests were selected together with spruce-dominated forests within the mutual uniform intact forests landscape (see the corresponding description above). Further, forest tracts were separated into pine and spruce forests on the basis of predominant tree spe-

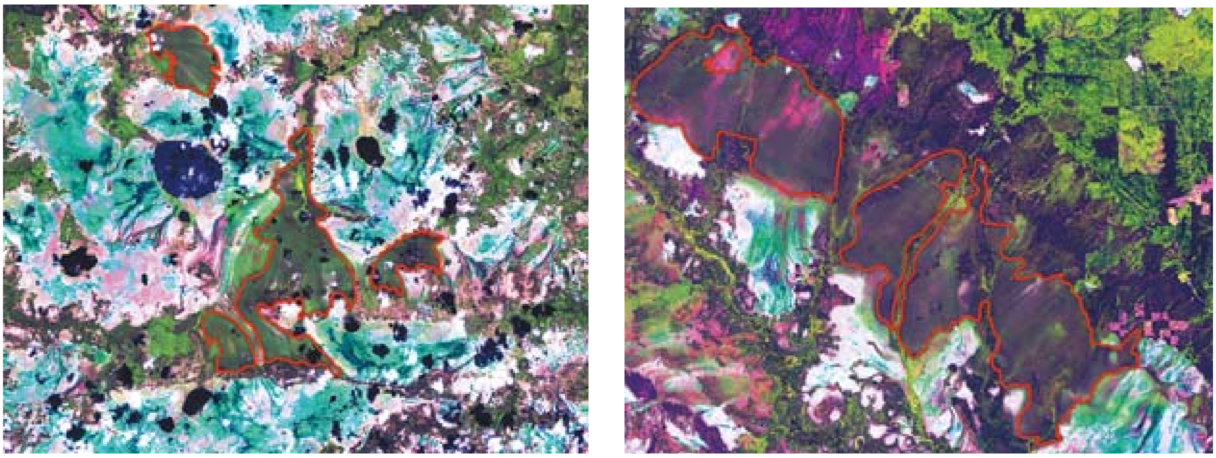

Fig. 2.10. Old-growth pine forests of *Sphagnum* and green mosses types in satellite images Landsat ETM +, (band combination 5-4-3). Arkhangelsk Region. The boundaries of potentially intact pine forest tracts are outlined in red.

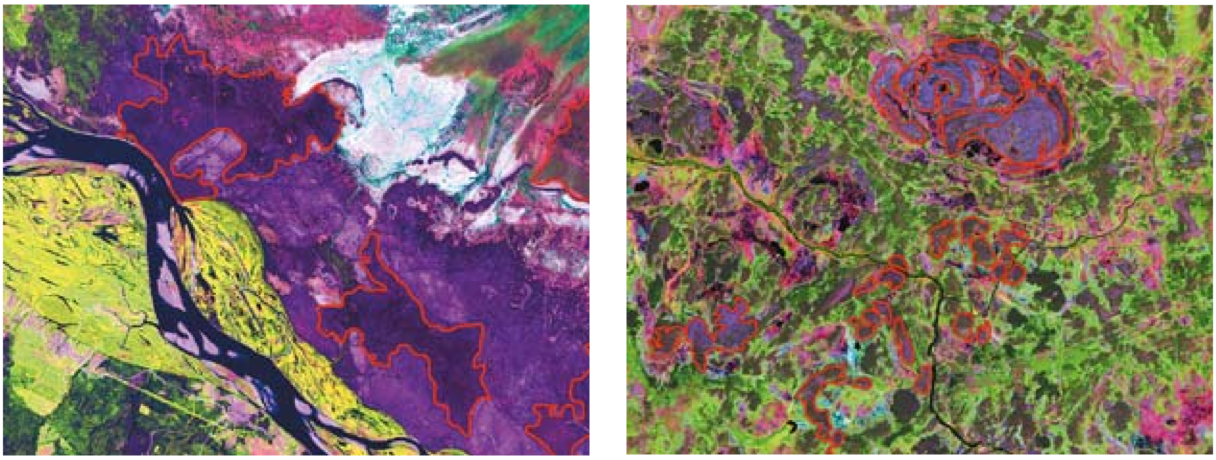

Fig. 2.11. Old-growth pine forests of *Cladonia* type in satellite images Landsat ETM +, (band combination 5-4-3). Arkhangelsk Region (left) and Murmansk Region (right). The boundaries of potentially intact pine forest tracts are outlined in red.

cies as shown by semi-automatic classification of Landsat images (see 2.3.2).

In **Arkhangelsk Region**, the potential locations of old-growth pine forests were initially determined from the generalized forest management scheme (scale 1: 500,000). We selected all pine stands which were indicated as "mature and over-mature ". The boundaries of pine forest tracts were divided into two groups: dark green (darker than secondary pine, broadleaved and mixed forests, but lighter than spruce forests), sometimes with gray, crimson, pink and yellow shades (*Sphagnum*, and green mosses types); and pink or crimson of varying intensity (*Cladonia* type).

Generally, mapping of old-growth pine forest follows the same principles as mapping of old-growth spruce forest. However, there were some features which need clarification:

- discriminating old-growth from young stands is especially difficult in pine forests of *Cladonia* type;
- boundaries between forest stands and mires for patches of pine forests of *Sphagnum* type located on micro-elevations have been marked only approximately;
- tracts of pine forests with traces of artificial drainage were not recognized as HCV areas.

Intact forest tracts of pine-dominated old-growth forests often incorporate a significant proportion of intact mire massifs dispersed throughout them like a mosaic.

Discrimination of forests on the basis of predominant tree species was performed using semi-automatic classification of the Landsat satellite images.

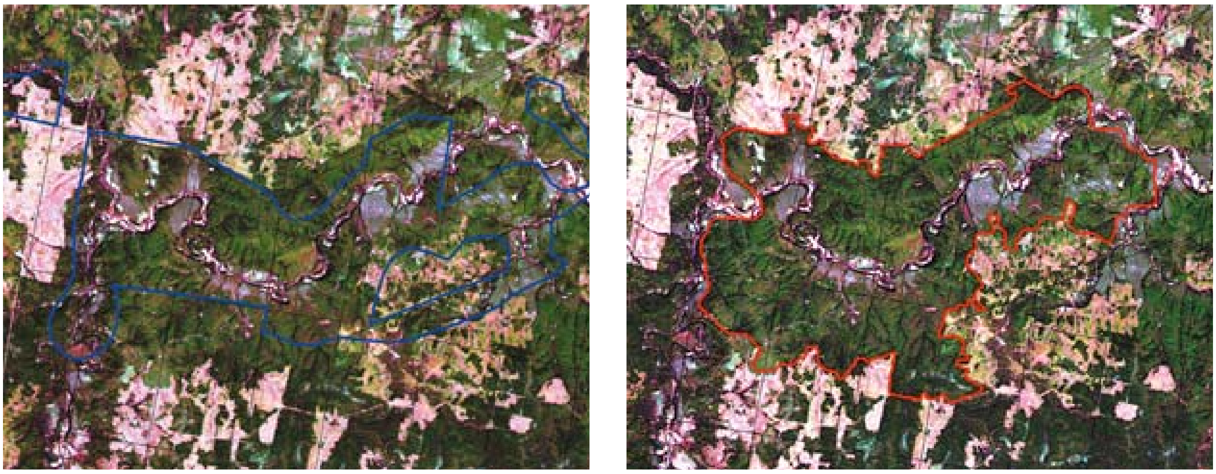

Fig. 2.12. Intact tracts of old-growth pine forests in Arkhangelsk Region.

Left: Generalized sites of pine-dominated forests indicated as “mature and over-mature” according to forest inventory/management data (Forest map of the Arkhangelsk Region, scale 1: 500 000). The boundaries of potentially intact pine forest tracts are outlined in blue.
Right: The same area with old-growth pine-dominated forests mapped on the basis of expert visual interpretation of satellite image Landsat ETM +. The boundaries of potentially intact pine forest tracts are outlined in red.

In **Vologda Region,** selection of the intact forest landscapes and the intact forest and mire massifs was performed by expert visual interpretation of the Landsat and SPOT satellite images. To verify the age of the forest stands and the scale of disturbance we used data obtained from the forest management database and by field surveys (2008, 2009 and 2010) of the particular plots previously identified as sites in need of additional field inventories. Field inventories were conducted jointly by the regional expert group and a partnership Transparent World, Moscow. Most of the sites subjected to field inventories were paludified pine forests of *Sphagnum* type, pine bogs, or forests confined to the valleys of major rivers. In accordance with the criteria previously described (see 2.3.1), we used the criterion of minimum size in selecting intact forest tracts for further study and mapping (see Table 2.3).

In **Leningrad Region**, we estimated the age of the pine-dominated forests chiefly on the basis of forest inventory data, as with the spruce-dominated forests. Direct approximate estimation of forest age from satellite images was possible only for large areas covered continuously by pine-dominated forests (see criteria, 2.3.1 above) with parallel study of the forest management database. Along with this, we analyzed forest inventory data and selected all sites indicated as "mature and over-mature" that exceeded 100 ha (see Table 2.3). As the next step, we combined the data obtained from all three sources, analyzed it and made additional corrections on the contours made by the satellite images. Field survey for the most complex sites was performed in 2010.

2.3.6 The sub-arctic mountain birch forest

The northern edge of the forest can be very diffuse in northern Russia. Moving north, the trees get successively smaller and the tree stand sparser. The boundary of the sub-arctic mountain birch forest given in this study does not coincide with the Russian category of "forest adjacent to tundra" which has a protection function. A genuine intact forest landscape often changes gradually into an equally intact tundra landscape. Old-growth spruce and pine forests that are situated on the northern forest boundary are included in previous subchapters. Here we analyze only a narrow belt of the montane-tundra open birch woodland dominated by *Betula pubescens* ssp. *czerepanovii*, of the *Empetrum-Cladonia* and *Empetrum-Myrtillus* types. In northwest Russia it forms the ecotone between the boreal coniferous forest and the alpine areas, and between the boreal coniferous forest, tundra and the coastal biotopes. Mountain birch forests growing on the upper mountain slopes (above 350-400 m), usually have very low density and measure 3-5 m in height, with typical curved trunks, sometimes shrubby in habit. They may be interspersed with spruce and *Juniperus communis* ssp *alpina*. Even after a single impact, these forests, as a rule, do not regenerate because of the harsh conditions, and are replaced by tundra vegetation.

In this study, we selected intact areas and intact tracts of mountain birch forest only in **Murmansk Region,** where all forest sites of this type are old-growth, preserved either intact or minimally transformed owing to their low timber value and their status of protected forest. Some very rare occurrences of open birch woodland as narrow strips along lakes also in the northwest part of the **Republic of Karelia**, but they are not covered in this study.

The selection of mountain birch forest sites has been based on visual interpretation of Landsat satellite images. The main interpretive sign was the topological position of forests: usually they are situated along the northern edge of the forest zone, adjacent to the forest-tundra boundary in lowlands, or along the upper edge of forest in mountains. Mountain birch forests have a typical spectral pattern (Fig. 2.13) which allows them to be identified as sparse small-leaved forests, usually with a clear boundary with the treeless tundra zone in the north and the coniferous forest zone in the south.

As supporting information we used bitmap forest inventory data in a raster format, and the results of semi-automatic classification of the same Landsat satellite images using neural networks in the program ScanEx Image Processor, a module Thematic Pro (see 2.3.2).

Neither the limits on the minimum size, nor the scale of fragmentation and insular location of the open birch woodlands were considered obstacles to their selection for further study and mapping. We believe that the small size and insular location of the mountain birch forests, as well as their scattered distribution inside other landscapes, are natural feature of these biotopes. We only had to conduct a filtration of the mountain birch forest sites by size, to decide how to combine them with other biotopes into intact forest tracts.

Old-growth spruce and pine forests directly adjacent to open tundra landscapes, without a belt of mountain birch forests, are very seldom found in Murmansk olbast, only exceptionally in mountain areas. We have not selected them for study because of their small areas.

2.3.7. Intact mire massifs and mire biotopes selected within them

Mire biotopes were chiefly selected as possible HCV areas where they are situated within intact mire massifs. Isolated mire biotopes were not selected with the exception of certain particularly valuable mire types such as fens (i.e. peatlands mainly fed by water that has been in contact with the mineral bedrock/soil) including spring fens and sloping fens; also included were small-sized areas of aapa mires situated south of the aapa-provinces and outside the main distribution area of aapa mires in Northern Europe and Western Siberia. All these types of mire biotopes are described below.

Satellite images Landsat ETM + were used as the main source of primary information for the external borders of the intact mire massifs. In Vologda Region, we also used ALOS and SPOT satellite images as complementary data. However, although the information source was about the same in all the regions covered by this study, the methods of delineation of the external borders of the intact mire massifs were somewhat different, depending on the region.

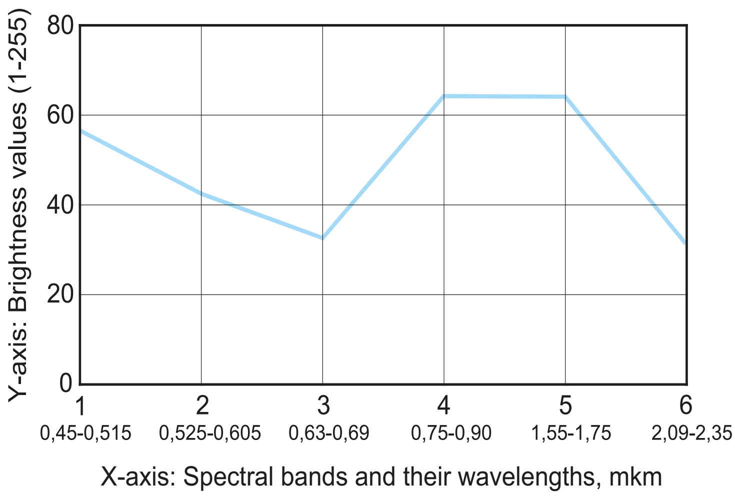

Fig. 2.13. A typical spectral portrait of a plot of mountain birch forest from satellite images Landsat TM / ETM +.

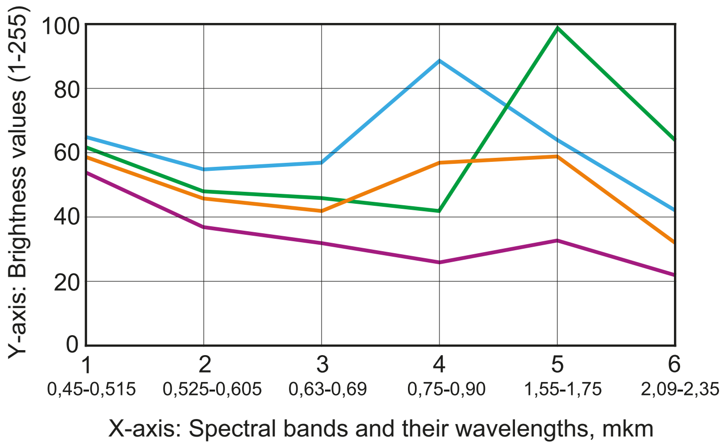

Fig. 2.14. Spectral characteristics of mire types obtained using semi-automatic classification of Landsat TM / ETM + satellite images. Blue line: open *Sphagnum* bogs (type 4); green line: sedge and grass fens (type 7); purple line: wet fens (type 8); orange line: pine-covered Sphagnum bogs (type 9).

In the **Republic of Karelia**, **Leningrad Region** and the City of **St. Petersburg**, the outer limits of the intact mire massifs were obtained from the results of semi-automatic classification of satellite images that was performed for the entire project area. To delineate outer margins of the intact mire massifs in the first stage, we have merged the four following types of mire massifs, distinguished by their vegetation, resulting from semi-automatic classification of satellite images (Fig. 2.14):

- type 4 –*Sphagnum* bogs;
- type 7 – sedge and grass fens;
- type 8 – wet fens;
- type 9 – mires covered with pine.

In the second stage, intact mire massifs that incorporate mire biotopes of different types were transformed into vector format, after which algorithms of smoothing and generalization were applied. This procedure caused the maximal accordance of the outer limits of intact mire massifs with the visually apparent boundaries in satellite images. In this stage we obtained the patterns of all mire massifs for the entire region, either intact or transformed. Further filtering according to minimum size eliminated all mires which covered an area less than 100 ha. Then, the data of the external borders of mires were transferred to regional experts for the final selection using the criteria of high conservation value (See 2.1.3) for the selection of intact mire massifs.

Mire areas in northwest Russia usually have a complex structure. Four basic structural categories, mire systems, mire complexes (massifs), mire sites and mire communities (cenoses) form the basis for describing the diversity of mire types in any large region (Yurkovskaya 1971, 1995). A mire massif – a continual pattern of the land surface covered by a mire and not crossed by mineral land – is a basic topographical unit of the mire landscape classification. A mire system includes several mire massifs hydrologically linked with each other (Botch 1999). In this study, we separated common mire types down to the level of mire systems and mire massifs. We identified them according to the most characteristic mire type that prevailed in the composition of the mire system; for example, in the Republic of Karelia, all mire systems appeared to belong to aapa or *Sphagnum* types. The rare mire types, e.g. eutrophic fens, were identified to the level of mire sites and to the level of mire communities for the rarest.

In **Murmansk, Arkhangelsk and Vologda Regions** we started to delineate the boundaries of the mire massifs from the expert visual interpretation of satellite images. In most cases, mire biotopes have very distinctive spectral portraits and quite sharp boundaries with neighboring ecosystems in the satellite images (Fig. 2.16.). Therefore, as a rule, delineation of the visual boundaries on the satellite images was in most cases quite easy. The exceptions were sedge and grass fens, the spectral characteristics of which are close to those of meadows and clear-cuts overgrown with grass. However, sedge and grass fens can be visually discriminated from meadows and clear-cuts by the shape of their borders with neighboring ecosystems. In uncertain cases, we used winter satellite images in which the open parts of sedge and grass fens are distinguished from forested areas much more sharply than in summer images. Finally, in some cases, the boundaries of the sedge and grass fens delineated by visual interpretation of satellite images were compared with topographic maps (scale 1: 100,000 – 1,200,000) in raster format, maps of forest inventory data, and the data of peat resources.

Generally, boundaries of intact mire massifs were delineated to include only the exposed parts of the mires, whereas all other communities, primarily tree-covered parts, were excluded (except for the *Sphagnum* bogs covered with sparse pine forests and pine mires).

The final selection of the intact mire massifs that match the criteria of HCV areas was made by the regional experts using the data of peat resources, forest inventory data, forest management materials, the data of field surveys, and other additional sources of information. In regions where the borders of the intact mire massifs were defined by visual interpretation, the selection was simple: mires not satisfying the criteria for intact mire massifs were eliminated.

In cases where the outer limits of the intact mire massifs were obtained from the results of semi-automatic classification of satellite images, the regional experts made the selection from the full set of patterns of all mires in the region. The regional experts produced, where necessary, a manual adjustment of the boundaries of mires (systems) and their further division into separate mire massifs. Usually the borders between mire massifs were drawn in places where they were connected to each other only by narrow isthmuses of mire.

For the **Republic of Karelia** we possessed the largest amount of additional material on intact mire massifs. These materials are available at the mire ecosystems laboratory of the Institute of Biology of Karelian Research Center of Russian Academy of Science, Petrozavodsk. They are the result of long-term studies over more than sixty years, conducted by Ekaterina Galkina, Rimma Kozlova (Galkina

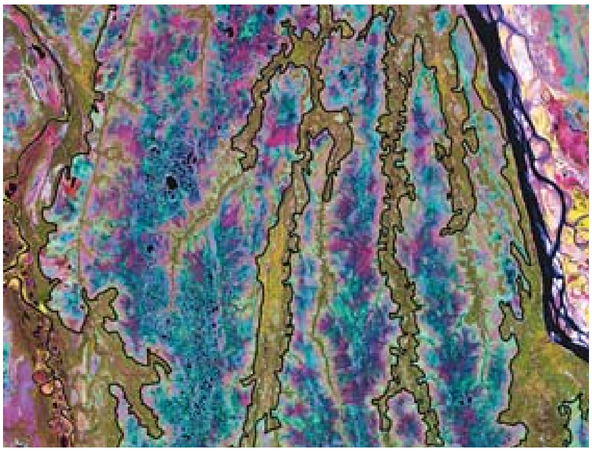

Fig. 2.15. An example of the delineation of boundaries of intact mire massifs. A large intact mire system in Arkhangelsk region called Koltsa ("the Ring Mire"). Satellite image Landsat ETM +.

1959, 1964, Galkina & Kozlova 1971), Tatyana Yurkovskaya (Yurkovskaya 1959, 1964, 1992, 1995), Galina Elina (Elina et al. 1984, 2010, Elina & Kuznetsov 2006), Oleg Kuznetsov (Kuznetsov 1980, 1993) and Pavel Tokarev (Tokarev 2005). Along with the scientific articles, we used a variety of thematic maps (see 2.2.) and data of peat resources (Peat resources … 1957, 1979).

The main criteria for the selection of the intact mire massifs were their size and the scale of anthropogenic transformation from the natural state. Mires of types that are considered rare in the study area, like spring fens, sloping fens, and aapa mires when situated south of their main distribution area (see below), were selected in every case, regardless of size and scale of transforma-

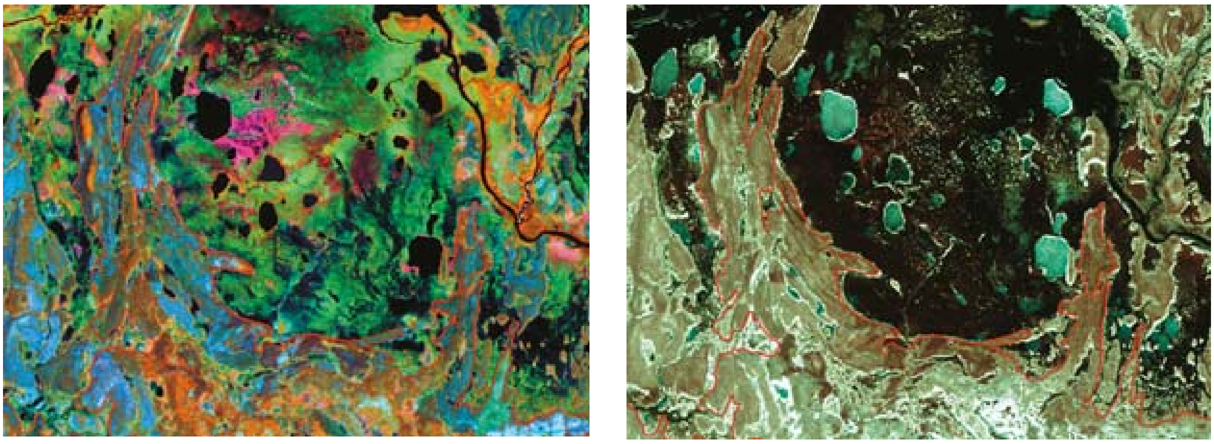

Fig. 2.16. An example of the delineation of boundaries of intact mire massifs in the middle reaches of the Ponoi River using a summer satellite image (left), and the correction of the boundary in the satellite image taken in early spring (right). The early spring satellite image allows better discrimination of the mire area and the patches occupied by tree and shrub vegetation.

Table 2.6. Minimum sizes of intact mire massifs mapped in the study, depending on region and type of mire.

Regions and mire types	Ombro-trophic	Minero-trophic
St. Petersburg	1,000 ha	300 ha
Leningrad Region	10,000 ha	500 ha
Vologda Region, eastern part	100 ha	50 ha
Vologda Region, western part	5,000 ha	300 ha
Republic of Karelia, dystrophic bogs on White Sea coast	20,000 ha	–
Republic of Karelia, excluding dystrophic bogs on White Sea coast	2,000 ha	1,000 ha
Murmansk Region	50,000 ha	
Arkhangelsk Region (Karelian, Onego-Dvina and Timan landscape provinces), excluding the White Sea-Kuloi Plateau, and the dystrophic bogs on White Sea coast.	15,000 ha	
Arkhangelsk Region, dystrophic bogs along White Sea coast to the west of the White Sea-Kuloi Plateau, to the border of the Republic of Karelia	10,000 ha	–
Arkhangelsk Region: White Sea-Kuloi Plateau, and the remaining territory of the Arkhangelsk Region	5,000 ha	

tion. Thus, all the mires which met the dimensional criteria and were not severely disturbed by drainage or peat extraction were considered HCV areas. (**Table 2.6.).**

In **Leningrad Region**, only very large mires exceeding in area 20,000 ha were generally selected as intact mire massifs. However, two-thirds of the selected intact mire massifs are, in fact, smaller, because they do not belong to types common in the area, so as rare types of wetlands in this region they were selected on criteria other than just size. These criteria are listed in 2.1.3.

In **Murmansk Region**, the selection of intact mire massifs was particularly difficult. The share of wetland areas in Murmansk Region is very high: the average percentage of paludification of the whole territory is 37%, reaching 60% in the eastern part of the region (Ramenskaya 1983, Ecological Atlas…1999). In fact, the entire eastern part is a single forest-tundra-mire complex which can not be separated into individual elements. For this reason, delineation of particular intact mire massifs from this complex wetland system was not performed in the same way as in all other study areas.

Even if we restrict the number of the study objects and choose only open mires for further study and mapping, we find that there are too many mires within the size range 3,000 - 30,000 ha. Therefore, based on the estimations of the minimum size of a nature area for it to fulfill its purpose regarding environment protection functions, given in Rudis & Tansey (1995) and in Sokolov et al. (1997), we used 50,000 ha as the minimum size of mire, and 10 km as its minimal linear dimension. In fact, there is only one intact mire massif in Murmansk Region that meets these size criteria and was therefore selected. It is a huge mire complex covering a vast plain called the Ponoi depression, in the middle reaches of the Ponoi River (fig. 2.16).

Rubus chamaemorus grows and fruits only on intact mires. Photo: Gennady Aleksandrov.

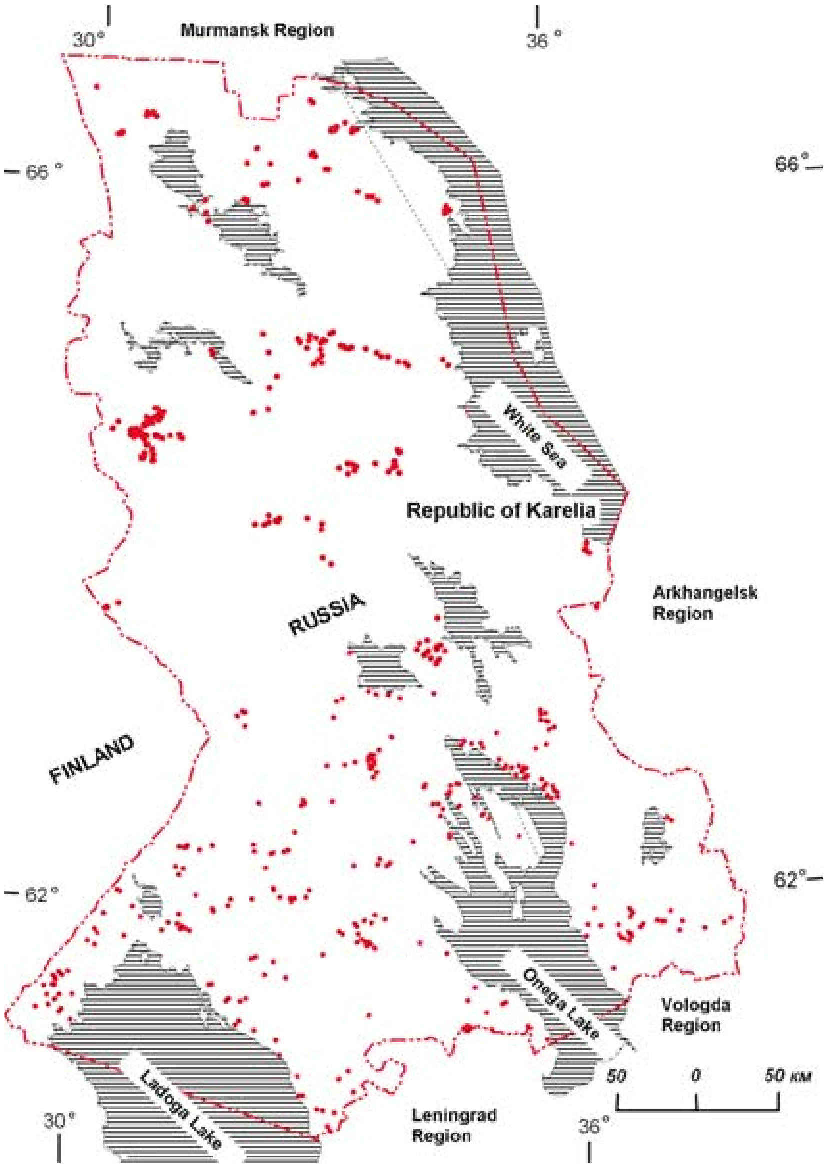

Fig. 2.17. Map of the mires (red dots) studied by the researchers of the mire ecosystems laboratory of the Karelian Research Centre of Russian Academy of Sciences, Petrozavodsk.

Fig. 2.18. An example of a typical section of territory in southeast Murmansk Region. About 60% of the territory is occupied by different types of wetlands; the remaining area is covered with forest vegetation and water.

2.3.8. Spring fens

A characteristic feature of spring fens is that they are fed by artesian groundwater and appear on the surface as springs or brooks. Usually, spring fens are small areas (from tens of square meters to a few hectares). They very seldom exist as separate mire massifs but usually constitute parts of mire systems in combination with other mire types. Spring fens have a great variety of vegetation, ranked in the study area from herb-rich and herb-*Sphagnum* communities of mesotrophic and eutrophic fens. Among the rare and key species (i.e. species strictly confined to spring fens) of mosses and vascular plants found here are yellow marsh saxifrage (*Saxifraga hirculus*), chickweed willow herb (*Epilobium alsinifolium*), milk flower willow herb (*Epilobium lactiflorum*), early marsh orchid (*Dactylorhiza incarnata*), Siberian groundsel (*Ligularia sibirica*), bird's-eye primrose (*Primula farinosa*), common butterwort (*Pinguicula vulgaris*), bog adder's-mouth orchid (*Hammarbya paludosa*), and marsh helleborine (*Epipactis palustris*). Green mosses are often predominant in the moss cover.

Spring fens cover a very limited area even in regions where they are not very rare (for example, in Murmansk Region). Their very specific vegetation types, usually harboring sets of rare and threatened species, mean that all the spring fens found in the study area meet the HCV area criteria as rare plant communities and deserve to be mapped.

We selected spring fens using suitable topographical maps in combination with detailed field studies. In **Murmansk Region**, spring fens were selected during the field work conducted by the researchers of the Polar-Alpine Botanical Garden & Institute of Kola Research Center of Russian Academy of Sciences (Apatity) and the NGO Kola Biodiversity Conservation Center (Murmansk). In the course of field work the researchers accurately defined the entire area showing typical structural and floristic characteristics of spring fens. For those spring fens with the greatest species richness of plants, proposals for the establishment of nature monuments were immediately put in preparation. At the moment of writing, one of them, the nature monument "Eutrophic spring fen in the southern Khibiny foothills", has already been established, and two others are in progress.

For all other regions, we possessed only information of the locations of spring fens, but the exact delineation of their boundaries was not available. We had to select the area of spring fens approximately which, taking into account their small areas, was considered an acceptable method. In **Arkhangelsk Region** 28 formerly known locations of spring fens were mapped. For the **Vologda** and **Leningrad Regions** we mapped spring fens first using data from the literature and then created layers which show their boundaries and vegetation using data from field surveys during this study and other projects. In the **Republic of Karelia** only one large spring fen was mapped with its exact boundaries by the regional experts, as a result of their field inventory studies. Other spring fens, which are widely distributed on the slopes of the Maanselkä hills and West Karelia elevations, on the Zaonezhye Peninsula and in some other areas of the republic where they have been found and described in detail (Yurkovskaya 1959, Elina & Kuznetsov 1977, 1994, Kuznetsov et al. 1996, 2000), are not covered in this study. On the slopes of hills, spring fens often exist as components of sloping fens (see 2.3.9), and it is almost impossible to separate them.

Selection of spring fens using topographical maps and supported by adequate verification from satellite images was carried out only in **Murmansk Region**. First, we searched from topographic maps (scale 1:200,000, 1:100,000 and 1:50,000) of the territory occupied by mires with symbols of "spring" or "brook". These mire were delineated in the map. Further, the boundaries were corrected by interpretation of the satellite images. Many types of mires were excluded at this stage on the basis of their vegetation, e.g. lichen and small shrubs types, but not sites covered with whortle-leaved willow (*Salix myrsinites* L.), which is usually confined to spring fens. Many other types of mires were retained because the impact of spring output, as a rule, extends to adjacent parts of mires, even if they belong to other mire types. These places are characterised by especially high species diversity and presence of rare and threatened species.

The method used for selection of spring fens shows a rather high accuracy. An example of mapping of spring fens in Murmansk Region is given in Fig 2.19, which shows how the area rich in springs (blue dots) was represented in the topographic map and how this area has been analyzed from a Landsat TM satellite image. Data obtained from the satellite image were pre-selected for further study and subsequently supported by the field studies of the regional experts. They found that seven of the eight springs indicated in the topographic map have in their immediate surroundings typical features of spring fens. The eighth spring indicated near the left edge of the

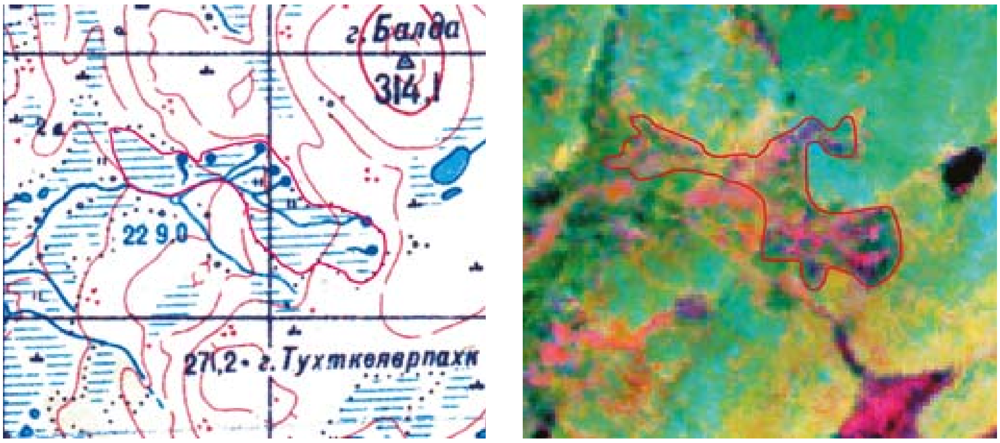

Fig. 2.19. Selection of spring fens: how the spring fen was represented in the topographic map (left) and how it is analyzed in a Landsat TM satellite image (right).

picture is probably erroneusly figured in the topographic map, because regional experts did not find any spring there during field observations.

In Murmansk Region we allocated 354 spring fens totaling 10,500 ha. This is more than in all other regions combined.

2.3.9. Sloping fens

The term "sloping fens" was introduced for the first time by the Finnish mire scientists. Sloping fens were described by Väino Auer (Auer 1922) from the present area of the Paanajärvi National Park in the Republic of Karelia. Further, sloping fens were thoroughly studied (Havas 1961, Elina & Kuznetsov 1994, 2003, Huttunen 2007). The sloping fen constitutes its own type of unstructured fen, situated not on low land or other flat surface, but on rocky slopes along the flows of surface or groundwater. It is characterized by rich species pools of herbs and green mosses. Sloping fens are widely distributed in Murmansk Region and the Republic of Karelia, but they are small in size and often look like patches or narrow strips (up to tens of meters) in the valleys of mountain streams. Sometimes a cascade of sloping fens, usually in combination with spring fens (see 2.3.8) occurs on the same slope. Their peat deposits are shallow (up to one and a half meters), or peat is absent.

Their particular diversity is the result of being well supplied with mineralized waters. This allows the maintenance of several rare plant species, like the frog orchid (*Coeloglossum viride*), mountain orchid (*Leucorchis albida*) and white Arctic mountain heather (*Cassiope tetragona*) (Konstantinova (ed.) 2009, Koroleva 2009). Sloping fens can be considered rare plant communities on the basis of both floristic criteria (presence of several rare species) and ecotopic criteria (distribution in specific soil conditions and microclimate features), i.e. criteria B, F and G of HCV areas (see 2.1.3).

Sloping fens, even if they are aggregated in a group (cascade), occupy very small areas. This circumstance does not allow their selection directly from satellite images. Therefore, we have mapped all sloping fens in this study only on the basis of data obtained during field surveys by regional experts. Due to their small areas, sloping fens were drawn on the maps as points. In fact, only Murmansk region, which is especially rich in sloping fens, was covered by field searches for sloping fens carried out by researchers from the Polar-Alpine Botanical Garden/Institute of the Kola Research Center of Russian Academy of Sciences, and experts from the NGO Kola Biodiversity Center. Consequently, sloping fens are mapped only in Murmansk Region, whereas in the maps of all other regions resulting from this study, sloping fens are missing. For instance, in northern parts of the Republic of Karelia adjacent to Murmansk Region, e.g. in the Maanselkä upland, and southward, e.g. in the West Karelian upland, sloping fens exist but were not mapped in this study.

2.3.10. Aapa mires outside their main distributional areas (aapa-provinces)

The aapa mire is a widespread mire type in the northern and middle boreal forest subzones of West European and East Siberian plains, and in parts of boreal Canada. They constitute the most characteristic type of mire massifs throughout the northern part of the study area, especially in Murmansk Region and the Republic of Karelia (Tsinzerling 1932, Yurkovskaya 1992). According to Elina et al. (2010), it is precisely aapa mires that make the plant cover of East Fennoscandia so specific. We selected aapa mires as intact mire massifs with conservational value only in the area to the south and south-east of their main distributional area (or Kola and Karelia aapa-provinces) defined by Botch & Masing (1979), in an area where aapa mires are gradually becoming rare. Thus, in this study, all aapa mires were selected throughout Vologda Region and in southern parts of Arkhangelsk Region, and in southern parts of the Republic of Karelia. In contrast, in northern part of Republic of Karelia only aapa mires over 1000 ha wide were mapped, and special aapa mire mapping was not conducted at all in Murmansk Region, which lies entirely within the area of their main distribution, nor in Leningrad Region, where aapa mires are either very rare (Botch 1990), or absent, according to the regional experts.

Aapa mires have an oligotrophic margin structure of plant cover, and are concave, elongated and sloping along the traverse. Eutrophic-mesotrophic and mesotrophic vegetation consisting of herbs and herb-brown moss patches alternating with open pools and *Sphagnum* strings prevail in the centre, while meso-oligotrophic and oligotrophic *Sphagnum* communities occupy the margins (Elina et al. 2010). String-flark and string-flark-pool complexes are the most typical elements of the aapa mire massifs. Strings are usually occupied by grass-*Sphagnum* communities, while very moist hollows maintain herbal or sedge-moss communities. Some flarks have been classified together with pools (i.e. the secondary lakes) without vegetation. All these typical characteristics enable the exact recognition of aapa mires on satellite images. The main signs of aapa mires visible on satellite images and aerial photographs are the absence of woody vegetation, high water content, and the specific pattern of narrow transverse strings and broad flarks and pools dispersed throughout them in the central parts of the aapa massifs. However, this definition based on Tsinzerling (1932) is not universal, there are different patterns of aapa mires depending on the sloping gradient of the mire and the amount of water flowing through the mire.

During the process of selecting and mapping it is necessary to consider that massifs of aapa mires are often combined with raised bogs of various types and have significant differences in shape and size, from relatively small areas to huge ones like the Ypäyzhsuo aapa mire system in Karelia, which exceeds 50,000 hectares (see 4.2.3). Generally, green colours in satellite images are typical for aapa mires versus brown colours of bogs.

In **Arkhangels**k and **Vologda Regions**, the selection of intact mire massifs containing aapa complexes was performed by expert visual interpretation of satellite images. In the southern part of the **Republic of Karelia**, we used semi-automatic classification of the Landsat satellite images. Several aapa complexes were also selected along the border of the **Vologda** and **Leningrad Regions** by the Vologda regional experts resulting from interpretation of satellite images supported by field inventories. Althought the definition of these objects as true aapa mires is still under discussion and needs further studies, we decided to select and map them in this study, because their structure, water supply and vegetation are very similar to aapa complexes in southern Karelia described in classic works of mire scientists (e.g. Elina et al. 2005).

In the preparatory phase, we analyzed satellite images Landsat ETM + (using two versions of fusion channels: 5-4-3 and 4-5-3). In Arkhangelsk Region we also analyzed aerial photographs.

In **Arkhangelsk Region**, string-flark aapa complexes selected after expert visual interpretation of the satellite images were subsequently verified by field surveys. As a result, 138 sites erroneously selected from satellite images (mainly located in the center and north of the Arkhangelsk Region) were subsequently excluded; on the other hand, 16 intact aapa complexes (mainly located in the north and northeastern parts of the Arkhangelsk Region) had been missed during the phase of visual interpretation of satellite images but were found during field studies and included. After that, all intact mire massifs containing aapa complexes that were found in Arkhangelsk Region have been mapped. Several aapa complexes adjacent to each other were delineated as an entire massif.

In **Vologda Region** intact aapa complexes were selected as entire mire massifs, together with other mire types. The boundaries of the aapa complexes inside these combined mire massifs were not distinguished. Preliminary results obtained from expert visual interpretation of satellite images were, in most cases, verified during consequent field inventory studies.

In the **Republic of Karelia**, the patterns of aapa complexes and their surroundings obtained from

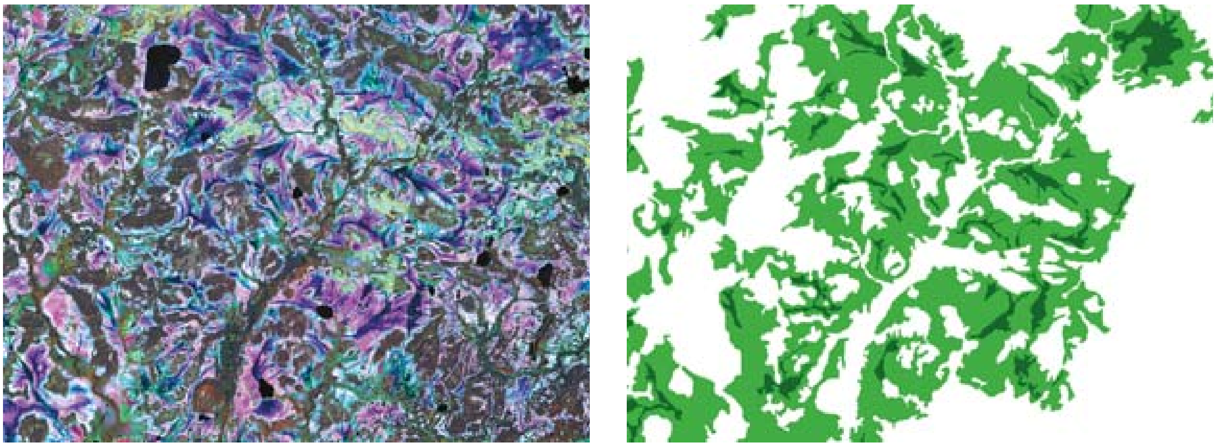

Fig. 2.20. Selection of the aapa complexes (dark blue in the left half of the picture representing Landsat ETM + image, dark green in the right half of the picture) and mire massifs containing them (light green on the right half of the picture, representing the map created on the basis of the satellite image). Arkhangelsk Region.

semi-automatic interpretation of satellite images were studied by regional experts from the mire ecosystems laboratory of the Institute of Biology of Karelian Research Center of Russian Academy of Science. They conducted a detailed classification of types of mire massifs within mire systems, which were selected on the basis of interpretation of satellite images. Mire massifs containing aapa complexes were further selected and mapped as intact mire massifs of the aapa type. According to Botch (1990) the southern boundary of the aapa mires is located near 62°30′ which corresponds to the southern boundary of the middle boreal zone, or the boundary between the north and middle taiga in the former Soviet Union. In this study, aapa mires situated in the Republic of Karelia roughly north to 64° latitude are not considered HCV areas.

2.3.11. Forest tracts with high restoration potential

Minimal transformation is the main criterion used for selection of forest landscapes and tracts as HCV areas. However, in some areas of northwest Russia, forest areas showing no visible signs of significant human activity, or disturbed only marginally, are too small and scattered throughout vast heavily transformed areas. They are clearly insufficient to preserve natural biodiversity and maintain ecological stability in the region. In this situation, tracts of secondary forests that have been cut but have regenerated without any management and retained their capacity for recover in a natural way deserve to be protected. This concerns the entire southern part of the study area, where the proportion of old-growth forests is extremely small. Forest tracts with high potential for natural recovery may differ in size and degree of transformation, but they must preserve their diverse ecosystem structure and harbor basic species pools of plants, animals, and fungi allowing them to maintain their basic environmental functions. Such forest tracts often have disrupted spatial structure (e.g. crossed by roads or including other man-made infrastructure) and incorporate invading species which could threaten the indigenous flora and fauna. However, we believe that they can recover their structure, which is close to natural for the region, in a relatively short time. Therefore, they have been selected as potential HCV areas in this study as forests with high restoration potential. In the study area, we have identified two types of forests with high restoration potential: mixed spruce-aspen forests and mixed birch-aspen forests.

Spruce-aspen forests

Mixed spruce-aspen forest tracts formed naturally after logging on the sites of former spruce-dominated old-growth forest were selected as HCV areas mainly towards the south edge of the study area, in **Vologda** and **Leningrad Regions**, and in the southern parts of **Arkhangelsk Region** and the **Republic of Karelia**. In **Murmansk Region** such forests were not found. In Arkhangelsk Region, however, although the majority of the HCV areas of this type were mapped in the southern part, several spruce-aspen forest sites have been identified also at more northern locations.

The main criteria used for selection of mixed spruce-aspen forest tracts were their large area and small scale of fragmentation. In fact, we selected the forest tracts which met the criteria described in 2.3.1. If a secondary spruce-aspen forest stand was adjacent to other types of HCV forest areas, especially those with old-growth spruce and spruce-

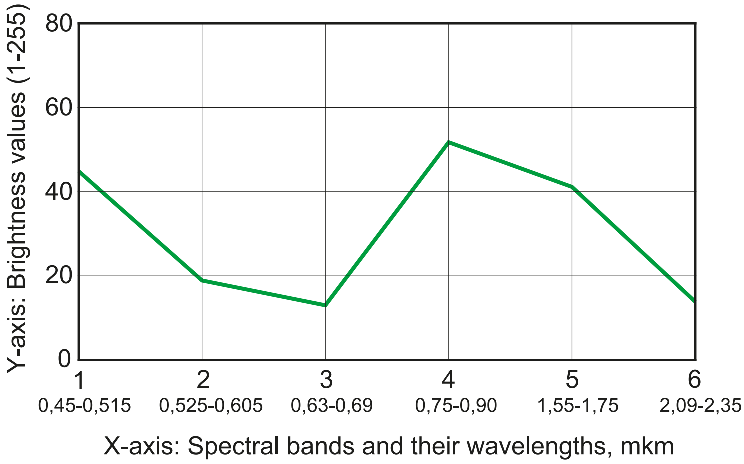

Fig. 2.21. Spectral characteristics of spruce and aspen in the channels of the Landsat TM/ETM+ images.

fir dominated forests, we always considered this as enhancing its conservational value. Patches of old-growth forest scattered throughout secondary mixed forest are the most valuable cores of the entire forest massif showing high potential for recovery in a natural way. The more patches of old-growth forest that exist within an area of secondary forest, the sooner it will be restored to its natural state owing to its proximity to old-growth forest, which can act as a source of the original species.

We selected mixed spruce-aspen forests by visual interpretation of the Landsat and SPOT satellite images using the combination of channels 5-4-3 for the Landsat or 4-1-2 for the SPOT images. The sites appear to be sufficiently homogeneous dark green areas interspersed with some dark brown and dark purple spots which indicate patches of old-growth spruce-dominated forests. Fig. 2.2.1. shows a typical spectral portrait of a mixed spruce-aspen forest massif, built by means of the ERDAS Imagine GIS program.

During the next step of the selection, we used the same criteria of size and fragmentation as for the old-growth forests (See 2.3.1). Verification of the preliminary results of visual interpretation and corrections of the boundaries of the selected forest tracts were made during field work in 2008-2010. Forest inventory materials were not used in the selection of this type of HCV forest areas.

Birch-aspen forests

This forest type is very similar to mixed spruce-aspen forest, and was selected and mapped on the same territory: the entire Vologda and Leningrad Regions, and in the southern regions of the Republic of Karelia and Arkhangelsk Region. Generally, there are two classes of mixed forests: spruce-aspen forest (i.e. mixed forest dominated by spruce and aspen with some birch); and birch-aspen forest (chiefly deciduous, dominated by birch and aspen but with some spruce). During visual interpretation of satellite images, it was not always easy to find a clear boundary between them. In some cases the boundaries were so faint as to be almost non-existent. Therefore, for the final analysis and for display on the maps these two types of secondary forests were combined into a single category: forest tracts with high potential for natural regeneration.

Selection of birch-aspen forests was also performed by visual interpretation of the Landsat and SPOT satellite images using the combination of channels 5-4-3 for the Landsat, or 4-1-2 for the SPOT images. The sites appear as homogeneous bright green areas (noticeably brighter and more homogeneous than spruce-aspen forest) and, as a rule, without dark brown or dark purple spots, which means no inclusions of dark coniferous forest patches. Fig. 2.2.2. shows a typical spectral portrait of a forest massif dominated by birch and aspen, built by means of the ERDAS Imagine.

The size and fragmentation criteria described in 2.3.1. were used for further selection. Data from field surveys by the regional experts were used for final delineation of the boundaries of forest tracts on the maps. Where the detailed forest inventory data were available, e.g. in Vologda and Leningrad Regions, we used the presence of broadleaved trees in the composition of the selected forest tracts as an additional criterion enhancing its conservational value.

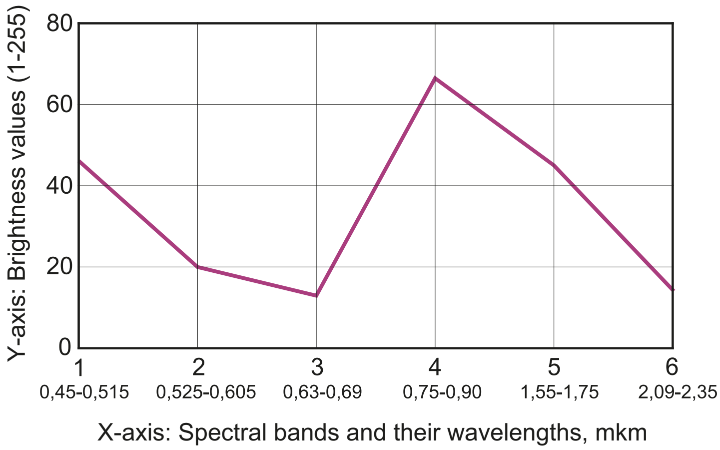

Fig. 2.22. Spectral characteristics of secondary forest dominated by birch and aspen in the channels of the Landsat TM/ETM+ images.

2.3.12. Dry pine-dominated forests confined to sandy dunes, rocks, shores of large rivers and lakes

Moisture-deficient (rupicolous, *Cladonia* and *Calluna*) forest types occur on nutrient poor and dry sandy sites lying mostly in the northern boreal and middle boreal forest sub-zones. They may also occur in the more southern forest sub-zones as very rare forest biotopes. They form principally on exposed crystalline rocks, on south-facing esker slopes composed of pebbly sand or on primitive podzols and also commonly on sand ridges within peatlands on glacial outwash or glacial lake plains. Only Scots pine (*Pinus sylvestris*) grows on such soils with *Cladonia* lichens predominant in the ground cover, hence the name of this forest type. In northwest Russia, dry pine forests are not necessarily related to the fire regime but are extra dry edaphic types on shallow fragmented soils. They are highly sensitive to anthropogenic disturbances. The majority of regional experts consider dry pine forest as a rare forest type having high conservational value – regardless of their degree of disturbance – in **Vologda** and **Leningrad Regions**, in the southern and middle parts of the **Arkhangelsk Region**, and in the southern part of the **Republic of Karelia**.

In the materials of forest management, dry pine forests are virtually indistinguishable from other pine-dominated forest types. Therefore, they can be distinguished using Landsat and SPOT satellite images but adequate support by further field surveys is essential to clarify the final boundaries of the forest tracts. On satellite images (combination of channels for 5-4-3 Landsat or 4-1-2 for SPOT images), dry pine forest sites may have two possible types of spectral portrait:

- Stands are sufficiently old, dense and, as a rule, confined to small oval-shaped elevations of the relief. They are almost always surrounded by pine forests of other types which look in the satellite images markedly darker than dry pine forest. In the images, dry pine forest has a uniform texture and brown-pink color with a characteristic pinkish shade

- Stands are of low density, or dominated by relatively young trees, while old trees are scattered within the forest site. Such stands are usually confined to slopes, heights, or elevations which are large in area but usually not high. They may occupy vast areas, but in these cases the entire territories were not selected as HCV areas. In the satellite images they have uneven, "grainy" texture, with aggregations of different sizes and shapes, various in color ranking from "dirty" light pink (which reflects a bare mineral surface) to shades of purple, brown, purple-brown combined with green, light green and yellowish patches. Some areas look like ordinary pine forest belonging to other types, more distributed in the area.

Fig. 2.23 shows typical spectral portraits of dry pine sites, constructed by means of ERDAS Imagine.

Along with visual interpretation of satellite images, dry pine forests were selected by virtue of their typical position in the landscape, and relation with certain geomorphological elements (the valleys of major rivers, esker ridges) or with certain types of

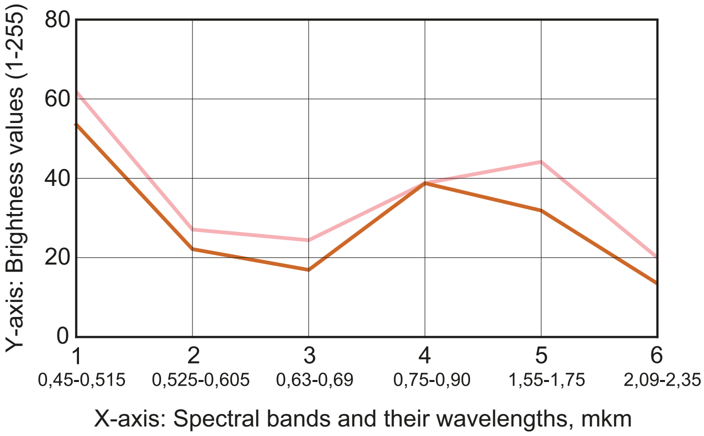

Fig. 2.23. Spectral characteristics of dry pine forests in satellite images Landsat TM/ETM+. The pink line shows dry pine forest on sandy dunes, the brown line other types of dry pine forests.

soil and geological conditions (e.g. dry sandy and rocky soils), using thematic geological maps and, in some cases, also topographic maps.

In **Murmansk Region**, the central and northern parts of the **Republic of Karelia**, as well as the northern part of **Arkhangelsk Region**, where dry pine forest types cover large areas and are not considered a rare forest type, they have not been selected as HCV areas and not mapped.

An exception was made for dry pine forests of *Cladonia* type growing on coastal dunes along the White Sea shore, in **Arkhangelsk Region**. They present a rare type of pine dominated forest. Dry pine forests on coastal dunes in the west of Arkhangelsk Region were discovered and studied for the first time by *P.N. Lvov* (Lvov 1971). In forest inventory data of Arkhangelsk Region, dune pine forests have never been separated from the group of lichen pine forests, so we could not use these materials in searching for this forest type. Most experts agree that in Arkhangelsk Region they are found only in particular sites along the White Sea coast, e.g. on Yagry Island near the town of Severodvinsk and on a number of islands in the delta of the Northern Dvina river (Kumbysh, Golets, Mudyug, and other islands).

In order to find dune pine forests on a topographic map, we used first a conventional sign, "sands" (Fig. 2.24. left), then we checked the forest type using forest inventory data. Boundaries of the dune pine forest sites were delineated by visual interpretation of satellite images Landsat ETM +, combination of channels 5-4-3 (Fig. 2.24. right).

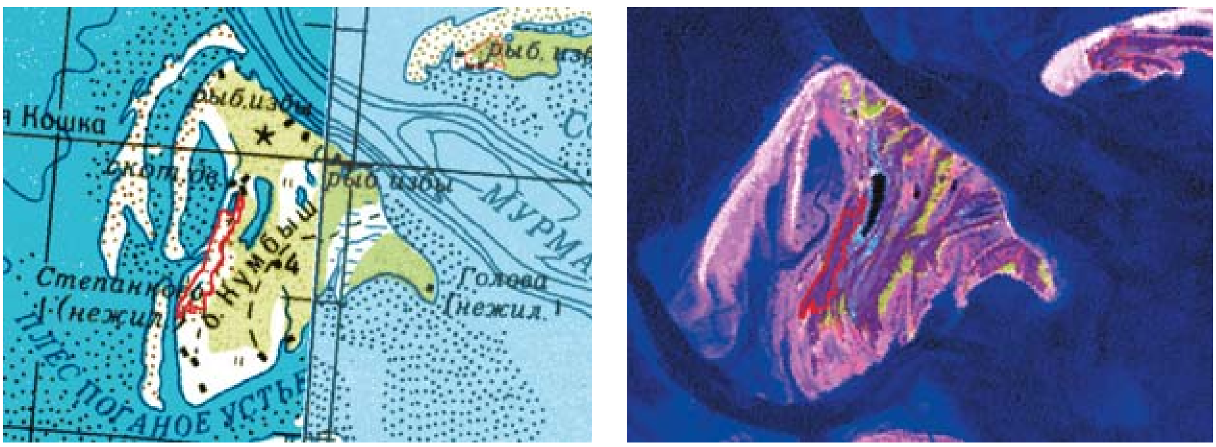

Fig. 2.24. Coastal dune pine forests on topographic maps (scale 1: 200,000, left) and on satellite images Landsat ETM + (right).

2.3.13. Old-growth, minimally transformed coniferous forests dominated by spruce and fir in hemiboreal and southern boreal forest sub-zones

In the vast majority of cases, the intact forest tracts identified in this study have a distinct southern edge of a clearly anthropogenic character. Often it is formed either by infrastructure or by agricultural land.

Nowadays, these forests belong to a forest type rare throughout the entire northwest of Russia. Formerly they constituted the principal forest type for large areas of the Russian Plain but have become extremely rare due to the vast scale of anthropogenic transformation of the indigenous forest areas. All surviving forest sites of this type of which the authors are aware, are old-growth forest in the late stages of natural succession. Their species composition and age structure are considered close to the natural. The presence of broadleaved deeiduous trees is an additional criterion of their high conservational value.

Old-growth, minimally transformed forests dominated by spruce and fir were selected as HCV areas only in the hemiboreal and southern boreal zones, in **the eastern part of Vologda Region** and in **the southeastern part of Arkhangelsk Region**. In other parts of the Arkhangelsk Region, coniferous forests with fir do not contain nemoral elements of flora so they were selected within the same intact forest landscapes and tracts together with spruce-dominated forests. In Leningrad Region, Murmansk Region and in the Republic of Karelia natural coniferous forests with fir are absent.

The selection of intact forest landscapes and intact forest tracts containing fir has been based on visual interpretation of satellite images. In Vologda Region we also used forest inventory data and data of field surveys conducted by regional experts. The criteria concerning the limits of minimum size and the scale of fragmentation were not applied. All forest sites identified by satellite images as old-growth forests dominated by spruce and fir were selected for further study and mapping. Their minimum size was about 1-2 ha. From our point of view, even such small areas of the remains of a formerly predominant forest type in the study area are worth careful consideration.

A typical spectral portrait of old-growth forest dominated by spruce and fir in the hemiboreal and southern boreal forests, built by means of ERDAS Imagine GIS program, is presented in Fig. 2.25. For comparison, the same figure incorporates the spectral portrait of the generalized old-growth forests dominated by spruce but containing also fir (see also Fig. 2.8).

The spectral portraits of the two types of coniferous old-growth forests look quite similar. Nevertheless, they can be discriminated. In the satellite images used for visual interpretation (combination of channels 5-4-3 for the Landsat, or 4-1-2 for SPOT satellite images), sites of intact southern taiga forests with large proportion of fir have a very distinctive dark color. In addition, they have typical texture features (the presence of numerous small specks of lighter tones) which probably reflect the areas' appearance resulting from gradual destruction of the upper canopy layer of the forest (natural "gaps" or "windows"). The boundaries between these areas and their surrounding envi-

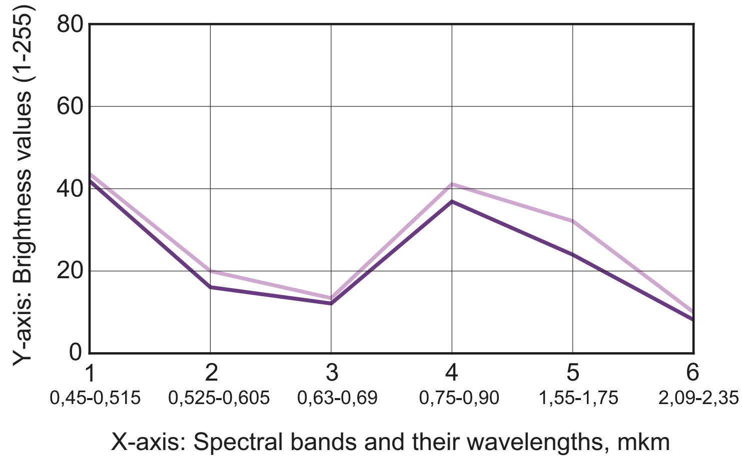

Fig. 2.25. Spectral characteristics of old-growth southern taiga forests dominated by spruce and fir from the Landsat TM / ETM + satellite images, in comparison with the spectral characteristics of other types of old-growth spruce-dominated forests. The light purple line indicates old-growth, minimally transformed forests dominated by spruce and fir; the dark purple line indicates other types of old-growth forests dominated by spruce.

ronments are usually very distinct. In most cases, they are preserved as relatively small areas, either surrounded by secondary mixed forest with spruce and birch dominant, or by birch-aspen forest (see 2.3.11), or by cut areas of different ages.

In the forest inventory data, old-growth forests dominated by spruce and fir are usually indicated as old-growth spruce forests without any specific mention of the presence of fir. Thus it has been essential to verify the results of visual interpretation of satellite images by field inventories in particular regions of Vologda and Arkhangelsk Regions. The results of such verification were further extrapolated to the entire territory where the old-growth coniferous forests with large proportion of fir are distributed.

2.3.14 . Broadleaved forests and mixed coniferous-broadleaved forests

In northwest Russia broadleaved and mixed broadleaved-coniferous forests occur chiefly in the hemiboreal zone or southern taiga. It is a transitional zone between the boreal and temperate forest zones, characterized by the coexistence of boreal coniferous (on poor soils) and temperate broadleaved tree species (on the most fertile soils). These forests used to cover vast areas in Leningrad and Vologda Regions and occurred in fragments in southern Karelia, but have been severely logged and have become replaced by secondary forests. Therefore, broadleaved and mixed broadleaved-coniferous forests are everywhere considered rare forest types. In this study, they were selected and mapped only in **Vologda** and **Leningrad Regions**. Large but severely fragmented areas of these forests in southern parts of the Republic of Karelia described by Yakovlev & Voronova (1959), Kuznetsov (1993), and indicated in the vegetation map of the Republic of Karelia (Yurkovskaya & Elina 2009) were unfortunately not included in this study.

Since on the satellite images both broadleaved and mixed broadleaved-coniferous forests are very difficult to discriminate from other deciduous and mixed forests, data of forest inventory were the main source of information. We analyzed the most recent of the available forest inventory data, and selected all forest sites where broadleaved tree species were indicated; such species included ash (*Fraxinus excelsior*), elm (*Ulmus glabra)*, maple (*Acer platanoides)*, lime *(Tilia cordata)*, and oak *(Quercus robur).* Fig. 2.26 shows a typical spectral portrait of a forest site including both broadleaved and mixed broadleaved-coniferous forests, built by means of ERDAS Imagine GIS program.

In **Leningrad Region**, the boundaries of these forest sites obtained from the forest inventory data were mostly further defined during field surveys using the navigation GPS. In **Vologda Region**, boundaries were only visually defined using interpretation of satellite images. Resulting from this, the final contours of the selected HCV areas in Vologda and partly in Leningrad Regions might incorporate not only forest sites containing broadleaved trees but also adjacent forests which are similar in their visual characteristics. The authors recognize that this approach could lead to the erroneous inclusion of fragments of forests where the presence of broadleaved trees was not confirmed by field surveys. Most of the selected HCV areas containing broadleaved and mixed broadleaved-coniferous forests are confined to river floodplains and the terraces above them. The dimensional criteria are not applied, i.e. all selected sites were considered valuable, regardless of their size.

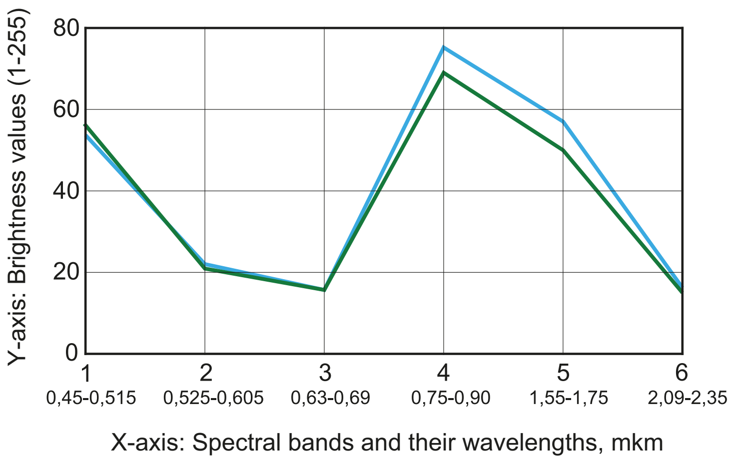

Fig. 2.26. Spectral characteristics of deciduous and coniferous-deciduous forests from satellite images Landsat TM / ETM +. Blue line: broadleaved forests; dark green line: broadleaved-coniferous forests.

2.3.15. Natural larch stands

In the study area, old-growth forests that consist primarily of larch trees (*Larix sibirica)* were selected in **Leningrad, Vologda** and **Arkhangelsk Regions**. We used detailed forest inventory data at the level of biotopes. From the forest inventory database we selected all forest stands in which the proportion of larch was 20% or more for Vologda Region, and 50% or more for Arkhangelsk Region, regardless of their age and the presence of other tree species. In other words, in Arkhangelsk Region, we selected only those forest stands which, according to the latest forest inventory, are predominated by larch. Larch is widely distributed throughout Arkhangelsk Region so forests with larch are very common and can not be considered as HCV areas based solely on the presence of larch (if it is not a dominant tree species). In Vologda Region, larch exists at the western limits of its natural distribution so forests with larch of natural origin are relatively rare. For this reason, we used different criteria for selection of forests with larch as HCV areas. The situation is similar in the easternmost part of the Republic of Karelia, where larch occurs in small numbers in pine-dominated old-growth forests, but they are not covered by this study.

Visual interpretation of satellite images was not used for selection of forests tracts containing larch because their spectral characteristics (Fig. 2.27) are very similar to those of pine-dominated light forests, either including or excluding larch.

Larch growing in mixed stands with other conifers gains an early height advantage over its associates. In the 1960s-1970s larch was planted on cut areas in the Republic of Karelia, Murmansk and Leningrad Regions, but nowadays it is not widely used for reforestation outside its natural range. Although no significant efforts have been made to determine its adaptability to other climatic or geographic zones, man-made larch plantations have been preserved in many places in the Republic of Karelia and Murmansk Region. They are not covered by this study due to their artificial origin. Three forest stands with larch initially selected in Leningrad Region were excluded both from the final analysis and from mapping because of their anthropogenic origin.

2.3.16. Coastal and continental grasslands

Grasslands were selected as HCV areas only in Murmansk Region. We divided them into four groups: (1) coastal grasslands, (2) tundra meadows, (3) grasslands along seasonally flooded riverbanks, (4) lowland and dry meadows. The vegetation of coastal grasslands has been well studied in the Republic of Karelia (Ramenskaya 1958, 1983, Babina 2002) and the results are indicated on the vegetation map of the Republic (Yurkovskaya & Elina 2009), but these data were not analyzed in this study. Similarly, continental grasslands, e.g. extensive massifs of dry meadows which are common in the Republic (Shennikov 1941, Ramenskaya 1958, Znamensky 2003), are not considered in this study.

Only areas of coastal grassland and tundra meadows (groups 1 and 2) are primary biotopes. All other types of grasslands (groups 3 and 4) in Murmansk Region are of secondary origin. They are the result of traditional agricultural methods and are mostly located in areas with a long history of agricultural use. Lowland and dry meadows occur on former forested areas (Ramenskaya 1958). Lowland meadows occur in wetter environments such as river valleys and temporarily flooded sites. Dry meadows

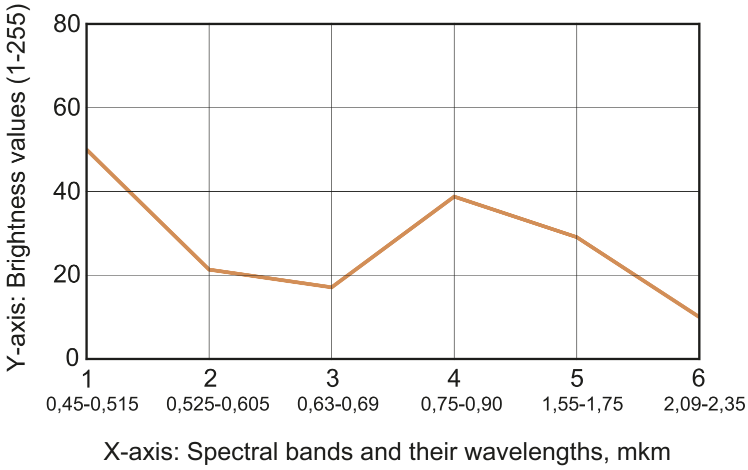

Fig. 2.27. Spectral characteristics of forests including significant amount of larch from satellite images Landsat TM / ETM +.

often occur next to fields and settlements, currently in use or abandoned (Kola Encyclopedy 2009). None of these types of grasslands were selected as HCV areas for this study owing to their semi-artificial origins. Although species pools of vascular plants in these communities might be quite rich, they are unstable and usually become overgrown by the original forest vegetation when abandoned.

Meadows confined to river valleys are usually in the form of narrow strips along the river banks or on islands. They occur both in the forest and tundra zones. Most often they are grass (*Poaceae*) and grass-herb meadows. There are also grassland communities dominated by *Carex* spp., *Calamagrostis* spp., *Scirpus cespitosus*, *Phalaroides arundinacea*, etc. and a variety of transitional forms. These communities, particularly herb and grass-herb meadows, may have high species richness. For instance, M.L. Ramenskaya (Ramenskaya 1983) and N.E. Koroleva (Koroleva 2008) indicated many plant species listed in the Red Data Book of Murmansk Region (2003), e.g. moonwort (*Botrychium lunaria*), northern moonwort (*Botrychium boreale*), dwarf milkwort (*Polygala amarella*), valerian (*Valeriana sambucifolia*), alpine lady's mantle (*Alchemilla alpina*), small white orchid (*Leucorchis albida*), low sandwort (*Arenaria humifusa*) and others. This allows considering them as HCV areas on the basis of the criteria of high species richness and presence of threatened and rare species. The fact that these meadows usually occupy very limited areas is an additional criterion enhancing their conservational value. However, all riparian meadows that were selected in Murmansk Region were already included in HCV areas of the valleys of small rivers and streams (2.3.19) or natural floodplain ecosystems along river valleys (2.3.20).

Tundra meadows are found in small patches on slopes with a uniform moisture flow. They are usually small but quite common in the tundra zone. Although tundra meadows have a specific floristic composition, they are not characterized by high species richness, nor are they habitats of any threatened or rare endemic species (Ramenskaya 1983).

The occasionally flooding flat or gently sloping shorelines of the White Sea and Barents Sea are characterized with extended wet meadows. Along low-lying coasts, saline (halophytic) meadows and floodplain grasslands with low salinity gradually merge into sedge and reed beds at different stages of development. The high salt concentration determines the presence of many specific halophilous species. Along coasts with minimal tidal range and sandy deposits situated beyond the area of flooding, wet meadows resembling those beside lakes and rivers have formed (Hallanaro & Pylvänäinen 2002). However, these meadows are impacted by salt spray so they also include a number of specific coastal plant species.

Coastal grasslands in the broad sense unite rather diverse groups of plant communities which have developed on rocky, sandy, loamy and clayey substrates. They are situated mainly in wave-sheltered parts of bays and inlets, both on the mainland and on islands in the Barents and White Seas. Some of these communities are particularly rare and unique (Koroleva 2008, Konstantinova (ed.) 2009). We selected all coastal grasslands for study and mapping as HCV areas on the basis of the following criteria: limited distribution, small size, high species richness, and presence of threatened and rare plant species (Chinenko 2008, Koroleva 2009). Many of these species are included in the Red Data Book of Murmansk Region (2003), for instance: Lake Huron tansy (*Tanacetum bipinnatum*), moschatel or five-faced bishop (*Adoxa moschatellina*), fringed pink (*Dianthus superbus*), *Arctanthemum hulteni*, *Armeria scabra*, boreal Jacob's-ladder (*Polemonium boreale*), tall Jacob's-ladder (*Polemonium acutiflorum*), common moonwort (*Botrychium lunaria*), northern moonwort (*Botrychium boreale*), and valerian (*Valeriana sambucifolia*).

About 90 % of coastal grasslands mapped in this study were selected during field surveys. The remainder coastal grasslands situated in remote and hardly accessible areas were selected on the basis of satellite images.

Salt marshes are not widespread in Murmansk Region. According to Kozhevnikov (1998), there are only quite small sites exceeding a few square meters in area that could be characterized as salt marshes, so they have not been specially selected in this study. Since on satellite images salt marshes resemble coastal grasslands, some of them could fall into this category as a result of erroneous visual interpretation.

The boundaries of coastal grasslands were delineated on the basis of visual interpretation of satellite images Landsat, SPOT 4, and Terra Aster. In some cases they were additionally clarified by QuickBird images, where they were available.

Several selected massifs of coastal grasslands are, in fact, coastal communities of the sandy wild rye (*Leymus arenarius*). Although the vegetation of these

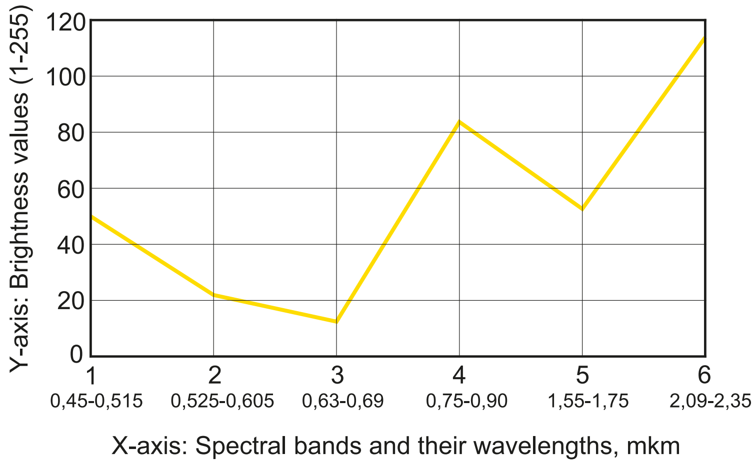

Fig. 2.28. Spectral characteristics of coastal grasslands in Murmansk Region obtained from satellite images Landsat TM / ETM +.

communities formed on coastal sands is usually characterized by relatively poor species composition, a few plant species confined to them are listed in the Red Data Book of Murmansk Region (2003), e.g. boreal Jacob's-ladder and tall Jacob's-ladder. These communities also have a very limited area of distribution so they have been included in the analysis.

In the final stage of the analysis we checked all grassland sites first selected as HCV areas from satellite images by careful study of topographic maps. Man-made meadows situated on the sites of abandoned fields and settlements are difficult to distinguish from natural grasslands in medium-resolution satellite images (Fig. 2.29), and were excluded from further analysis and mapping. As a result, a total of 150 sites of coastal grasslands covering a total area of 2,200 hectares were selected and presented on the final maps.

2.3.17. Alpine tundra areas in the forest zone

The alpine zone which is situated above the tree line lacks coniferous vegetation. The boundary between the subalpine woodland (usually mountain birch forest, but coniferous forest may form part of it) and open country in the mountains (the woodland limit) is often denoted as the height above sea level where the highest groups of trees can be found on mineral soil on south-facing slopes in areas of little human impact (Kålås et al. 2010). Open areas are home to broadly the same species of plants and animals found in the tundra zone. There are several tundra species of vascular plants, mosses and lichens which occur in the forest zone only here. Many animal species that occur in the alpine tundra often move between the woods and open fells (Hallanaro & Pylvänäinen 2002).

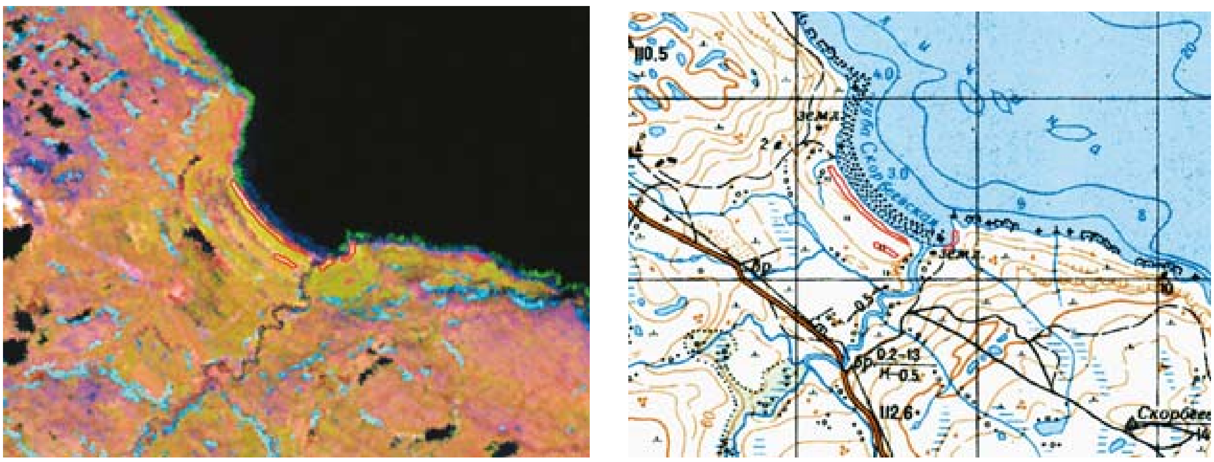

Fig. 2.29. Selection of coastal grasslands from satellite image (left), and the exclusion of meadows located on anthropogenically transformed territories from the analysis (topographical map, right).

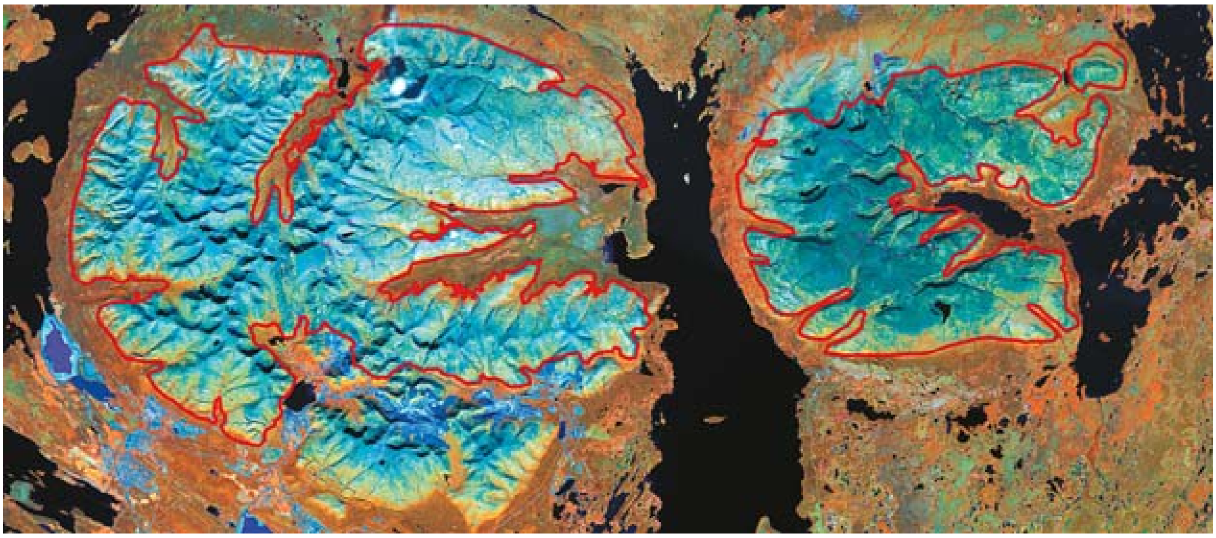

Fig. 2.30. Satellite images Landsat (band combination 4-5-3) of the Khibiny and Lovozero Tundras in Murmansk Region. The sites of mountain tundra have different shades of blue and are well distinguished from forest covered sites (light brown, yellowish, reddish and greenish).

In northwest Russia, alpine ecosystems within the forest zone are present on the tops of mountains in **Murmansk Region** and in the northern parts of the **Republic of Karelia**. They certainly represent a rare type of intra-zonal biotope, maintaining several endemic species (Ramenskaya 1983, Konstantinova (ed.) 2009). Mountain tundras are very sensitive to human impact. Many areas of formerly intact mountain tundra biogeocenoses are now being destroyed by mining, construction of ski resorts and reindeer overgrazing. Air pollution in the vicinity of metallurgical plants in Murmansk Region is a permanent destructive factor leading to the gradual decline of mountain tundras.

Identification of intact mountain tundra sites was performed by visual interpretation of Landsat ETM+ satellite images of medium resolution. Initially, we delineated all non-forested areas which, according to the topographic maps, are mountain tops above 400-500 meters. Mountain birch forests (see 2.3.6.) were not included in the contours of the mountain tundra sites. The boundaries were delineated along the clearly visible ecotone area between treeless open tundra and mountain birch forest, or coniferous forests in those cases where the mountain birch forest belt was absent. In the final stage, we excluded from the contours of intact mountain tundras all territories significantly disturbed by mining and industrial emissions.

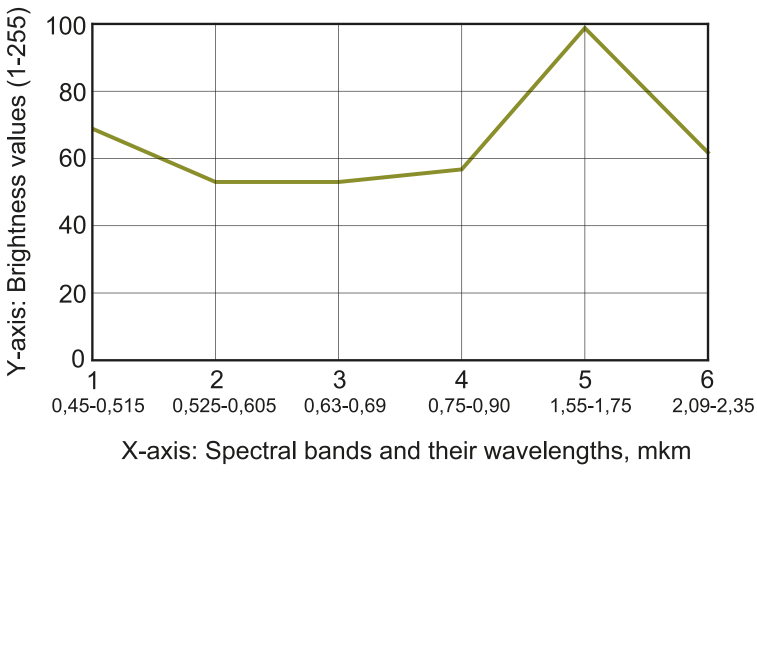

Fig. 2.31. Spectral characteristics of mountain tundra in Landsat TM / ETM + satellite images.

2.3.18. Gorges and rocky walls, deeply incised river valleys, canyons, ravines, cliffs

A large proportion of biodiversity in the boreal forest zone occurs in biotopes formed on steep slopes, boulders and rock walls, for example. They harbor very specific vegetation (so-called "rock vegetation") including species of lichens and bryophytes which are confined only to these habitats. The diversity of lichens and bryophytes there may be very large due to great variation in environmental conditions over short distances.

These biotopes were selected by visual interpretation of satellite images. They have characteristic shapes, e.g. gorges and deep river canyons look like crevices, and steep slopes throw typical shadows. In some cases, they are clearly marked on topographical maps as "cliff", "ravine" etc; in others the dense contour lines are an indirect indication.

The HCV areas with high diversity of specific rocky vegetation are widely distributed in different parts of the study area. In the territories situated on the Baltic shield, i.e. Murmansk Region and the Republic of Karelia (excluding its easternmost part), they are chiefly represented by gorges and rock walls, in other areas we selected deeply incised river valleys, ravines and cliffs.

In Khibiny, we were often unable to separate as single biotopes deeply incised canyons, valleys or cliffs where they are situated in close proximity to each other. We selected entire contours which include areas rich in crevices indicating gorges, canyons and deep river valleys, and areas with very rugged relief.

2.3.19. The ravines of small rivers and streams, brooks and seasonal streams

This kind of HCV area embraces a heterogeneous group of biotopes which often occur in the same territories. Stream ravines are landscape elements which often include screes and woodlands as well as one or more streams. We also included in this group some areas situated in the valleys of major rivers. Stream ravines and river valleys consist of a mosaic of steep slopes and small gorges with trees. The main feature of all these biotopes is higher moisture level in comparison with their surroundings. A variety of environmental conditions forms the basis for great biological diversity within small areas. Often they have the properties of local refuges: a more stable microclimate, lower risk in case of fire, and lower risk of human impact due to their inconvenience for many traditional activities, e.g. logging or construction. Thus most of these biotopes have been little affected by anthropogenic transformation and have kept their intact state to a great extent.

Stream ravines and related biotopes were selected by visual interpretation of satellite images. They have a characteristic elongated shape and differ from their surroundings in color. In some cases they have the shape of a buffer zone along a clearly visible river channel. The presence of characteristic shadows can also be used to identify these objects on satellite images. To clarify their boundaries, we tried to compare satellite images with topographical maps; however, the only value of the maps was their clear delineation of watercourses. Generally, we tried to stick to geomorphological boundaries,

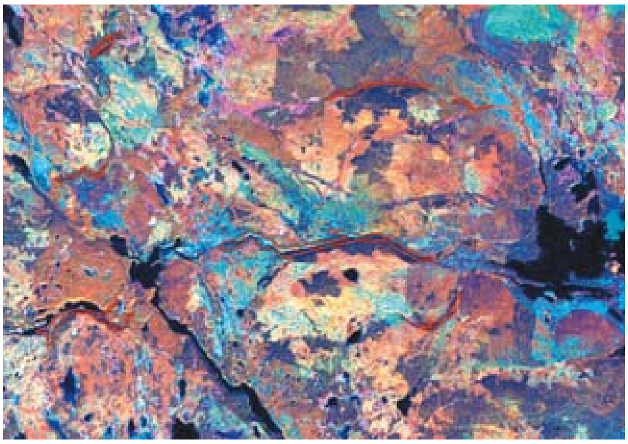

Fig. 2.33. An example of the selection of gorges, Murmansk Region. The Pyhäkuru gorge characterized by extremely high diversity of vegetation is situated in the center of the image. The nature reserve Kutsa, one of the first nature reserves in Finland, was established here in 1938. In 1940, this territory was annexed by the Soviet Union, becoming formally part of its territory under the terms of the 1940 peace treaty between the USSR and Finland. In subsequent years, the surroundings of Pyhäkuru gorge were greatly disturbed by logging and forest fires, though the gorge itself has luckily remained intact. In 1994, a complex zakaznik (i.e. special protected area) called Kutsa was established there. Transformation of this zakaznik into a national park is included in Russian Federation plans for development of the protected area network.

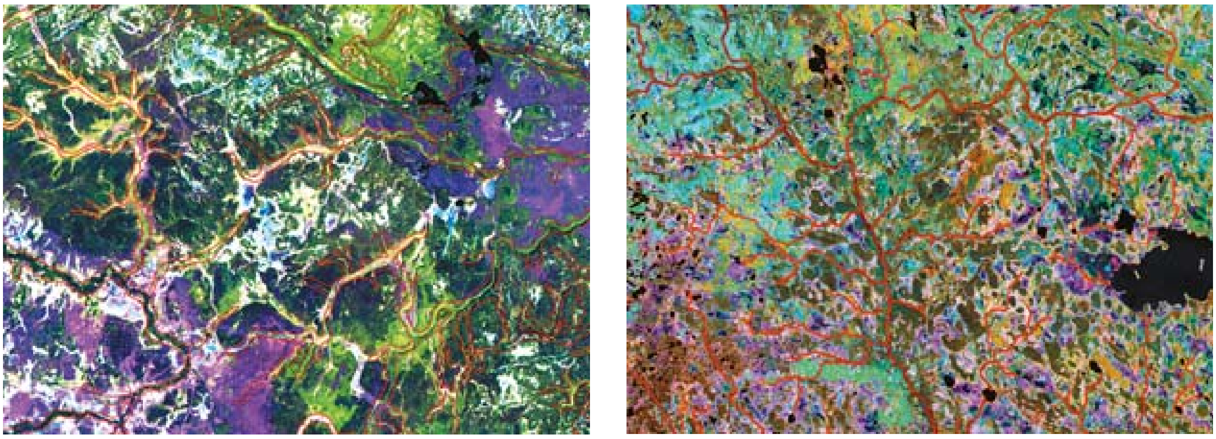

Fig. 2.32. Selection of small river valleys and stream ravines using satellite images. Stream ravines on the White Sea-Kuloi plateau, Arkhangelsk Region (left) and a valley of the Varzuga River, Murmansk Region (right).

as far as they can be identified by satellite images of medium resolution. However, we include in contours not only river beds but also adjacent wetlands, sometimes forming quite large bands a few dozen to hundreds of meters along the edge of the visible river bed; the areas of the "mantle flow"; and small hollows, where they were distinguishable in the satellite images, etc. These areas adjacent to stream ravines harbor high species diversity because of the numerous complex microhabitats found there.

Areas with relatively less disturbed vegetation along streams and brooks may be preserved even in severely transformed areas, e.g. by settlements, including big cities. They are clearly visible on satellite images. We excluded them from the analysis only in the significantly disturbed areas if they were not clearly distinguished by the type of vegetation from their surroundings.

2.3.20. Intact riversides, flood plain complexes and other natural biotopes at the mouths of rivers

In this type of HCV area, we include all flood plains of the major rivers and some of the medium-sized rivers, except for obviously man-made sites with buildings, arable land and other cultivated areas. Flood plains occupy the boundary zone between water and land and are exposed to inundation, sedimentation and erosion. They are the transitional zone between rivers or lakes and adjacent land areas, and extend between the lowest and higher water levels (Kålås et al. 2010). In economically developed regions, it is precisely floodplain areas that can be preserved in a relatively less transformed state owing to periodical floods that make them unsuitable for many activities.

A large number of biotopes that are confined to the water-land ecotones of flood plains and river banks create high habitat diversity for many species of animals and plants. The occurrence of woodlands, which usually support rich species pools, shows that the disturbance effect of water is moderate and a stable moisture level is beneficial. Many insect species are attracted to the margins of water bodies where they find specific host plants associated with these environments. High humidity also reduces the risk of fire and contributes to the preservation of fire refuge habitats.

For medium to large rivers, the areas of natural flood plains are easy to distinguish in the Landsat and SPOT satellite images by their structure, as well as by the nature of the vegetation. As a rule, their boundaries are clearly visible as changes in the types of vegetation between flood plains and adjacent areas. Steep slopes in the transitions from plain to river valley, which are usually indicated on topographic maps, serve as an additional guideline for boundary delineation. We excluded from the contours of floodplain HCV areas the riverbed itself, as well as sand bars and islands. The boundaries were defined along the visible border of vegetation. However, islands periodically inundated by flood water and covered with vegetation were included in the entire contour of the floodplain. The borders of oxbow lakes, small channels, inlets and other elements within the contour of the floodplain were not specially allocated. That is, we include in the contours of flood plains all the terrestrial biotopes located within them. The exceptions, as in all other cases, were severely disturbed biotopes.

The borders of woodlands which occur along larger rivers were always included in the contours of floodplains but their boundaries were not specially delineated within the contour. They are characterized with complex structure of different forest types, including forest dominated by willow (*Salix)* with some birch (*Betula pendula* and *B. pubescens*), grey alder (*Alnus incana*) and common alder (*A. glutinosa*); coniferous forest with Norway spruce *(Picea abies)* and Siberian spruce (*Picea obovata*); as well as wet paludified forest comprising grey alder, common alder, silver birch, dark leaved willow (*Salix myrsinifolia*) and some spruce.

Communities at the mouths of small and medium rivers have been combined into one type of HCV area together with natural flood plains. Generally, they are similar in vegetation, although areas next to the sea may harbor specific halophilous species more characteristic of sea estuaries (2.3.21) and deltas (2.3.22). It was quite difficult, however, to discriminate the areas according to the gradient of water salinity without ground survey so this circumstance has been ignored in the mapping of HCV areas.

For the especially broad natural flood plains of major rivers of the Arkhangelsk and Vologda Regions, contours of HCV areas were selected in two steps. Initially, we defined the borders of the entire floodplain area, and then eliminated the visibly disturbed sections. Only those flood plain sites showing no traces of drainage, roads, buildings or arable land were considered natural or undisturbed. The same approach was used in the allocation of floodplain communities in the delta of the Northern Dvina River (2.3.22.).

For the flood plains and mouths of the smaller rivers, we defined their border in one step, i.e. either we considered the area as completely intact and included it entirely into the contour of the HCV area or, conversely, we considered the area as transformed and excluded it from further mapping.

A special approach was used in **Murmansk Region**. Here we allocated almost all the flat areas of flood plains wide enough to be visible on the medium-resolution images (about 50 meters wide). In the rugged relief and rocky habitats which are very characteristic for outcrops of crystalline rocks, such sites are quite rare and are of interest only because of their rarity. Almost all of them are intact natural ecosystems. Anthropogenically disturbed sites, which were further excluded from the analysis, constituted only a minor fraction.

2.3.21. Estuaries

The major rivers form estuaries where they flow into seas with significant tidal range; within these estuaries the tidal flows and river flows meet and intermingle. The natural features of estuaries constantly change as they gradually silt up and the river water finds new routes to the sea.

The rate at which rivers flow into the sea is affected by the rate of tidal currents. If the river flow is strong, suspended matter is carried beyond the river mouth and then deposited. These deposits are exposed at low tides and subjected to intense erosion during high tides. As a rule, the intensity of tidal currents and the effects of wave action on the shore decrease further up the river, and the mouth of the river becomes funnel-shaped. Estuaries may be semi-enclosed narrow bays, firths, the actual tidal estuaries, coastal lagoons, fjords, or rias. On the basis of the type of mixing of fresh and salt water and stratification, estuaries are divided into three

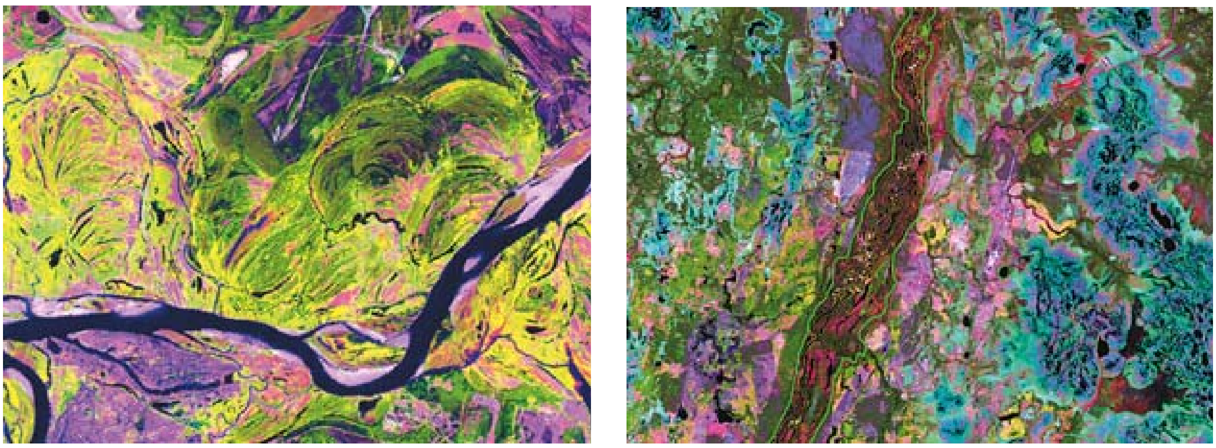

Fig. 2.33. Examples of floodplain ecosystems of major rivers in satellite images, Arkhangelsk Region. Segment-ridged floodplain of the Vychegda River (left) and a meander floodplain of the intermittent Kuloi River (right).

Fig. 2.34. The boundaries of the estuary funnel at the mouth of Onega River, White Sea, Arkhangelsk Region.

types: 1) with good (or complete) mixing, weakly stratified; 2) with partial mixing, moderately stratified; and 3) with minimal mixing, strongly stratified estuaries which include a "wedge" of saline water. Estuaries of the latter type are considered one of the most bioproductive aquatic ecosystems.

Along tidal coasts, wide inter-tidal mudflats are formed in estuaries where the weak tidal flow allows the material suspended in the river water to be deposited as silt, and the seawater mixes with the fresh water from upstream (Hallanaro & Pylvänäinen 2002). This makes estuaries harsh environments for most plants and animals, both physically and chemically. Few species can tolerate such conditions but those that can are often extremely plentiful. The high nutrient concentration in estuaries attracts large numbers of fish and waterfowl.

Specific environmental conditions associated with accumulation of alluvial material, the influence of the marginal filter and the activities of living organisms make the boundaries of entire estuary areas very clear in satellite images. We used Landsat ETM+ satellite images, with the band combination 2-3-1. The boundaries of the estuary funnel were applied to the coastline, while the borders of the estuary in the sea were traced through the boundaries of the alluvial deposits. Terrestrial ecosystems were not included in the borders of the estuaries but in cases of minimal transformation (i.e. the absence of human disturbance) they were referred to another specific type of HCV area, the complexes of flood plains and riversides at the mouths of rivers (2.3.20).

2.3.22. Deltas

In contrast to estuaries, for the formation of which the prevalence of rate of flow of the ebb currents over the tidal currents and lack of sediments in river mouths are necessary, river deltas are formed by a complex interaction of river flows, sea waves, tides and wind-tide currents. Deltas form when large quantities of sand, gravel and silt are deposited at river mouths. Rivers can split into several distinct channels with banks of different shapes and sizes formed of the various sedimentary materials. The formation of deltas on shallow sea shores begins with the appearance of short spits and estuarine submerged shoals. During floods those spits and shoals which remain above water become isolated from each other and turn into low-lying islands. Favourable conditions for rapid growth of deltas include an abundance of river sediment and a shallow water basin adjacent to the river mouth; in some cases lowering of water level or tectonic uplift of the coast. Position of the river mouth at the top of a bay or coastal lagoon partly or totally cut off from the open sea can have a major influence as well. Strong tidal surge and wind-flow together with rapid rise in water level (rapid tectonic subsidence) tend to prevent the formation of deltas. The rate of formation of river deltas varies widely, from a few meters to hundreds of meters per year.

Deltas situated in the tops of bays where wave erosion controls delta shape are called wave-dominated deltas, whereas those deltas situated on an open coast are called tide-dominated deltas. Deltas are typically classified according to their way of formation, shape, and stages of development. The following types of deltas are discriminated: 1) beak shaped deltas, 2) lobed deltas, 3) inland deltas, 4) extending deltas, 5) deltas with an open round outer edge, 6) deltas with many islands, for example the delta of the Northern Dvina River (Fig. 2.35), and 7) incised deltas, for example the delta of the Neva River. The latter type of delta forms in inland regions where the amount of sediment deposited is small and the sea level is low. The mouth of the river is divided into numerous branches incised into the sediments.

In this type of HCV area we include the entire range of terrestrial and aquatic ecosystems that occur in the river deltas. Other types of HCV areas, e.g. flood plains, shallows, mires, etc., which can be found within the entire area we define as "the river delta", were also included here in some cases because of difficulties in separating these usually small biotopes from each other.

Fig. 2.35. Delta of the Northern Dvina River. Arkhangelsk Region.

The upper limit of the delta was the first major branching of the channels forming the delta. The lower limit, i.e. the boundary of the delta with the sea, was traced through the boundaries of the alluvial deposits, well visible on satellite images, like those of estuaries. Anthropogenically transformed areas, for instance islands with settlements or other buildings, were excluded from the HCV area. The minimum size for this type of HCV area was 1000 ha. Using our methods, it is difficult to attribute smaller areas to river deltas with any confidence.

There are only three quite pronounced deltas in the study area, namely the Northern Dvina River delta (Arkhangelsk Region), the Neva River delta (St. Petersburg), and the merged deltas of the Mudyuga and Kadee Rivers (Arkhangelsk Region), that could be selected and mapped. In fact, only the latter two were fully mapped, whereas the delta of the Northern Dvina River was mapped only in its natural parts, excluding the urban areas within the city of Arkhangelsk and its satellites. The delta of the Neva River is entirely within the vast urban area of St. Petersburg, so it was totally excluded from consideration.

2.3.23. Shallow water, littorals and inter-tidal sandy shoals

The sea coast and littoral zone include both littoral and terrestrial biotopes. These biotopes are quite specific and are rich in nutrients originating in the sea. Many of these biotopes are key habitats for particular species of birds and fish, especially in the juvenile stages of their life cycle. In the White and Barents Seas this type of HCV area includes quite broad flat areas of the littoral zone.

We include here shoals and shallows of various kinds, from tide flooded rocks (rocky foreshore) to pure sandy shores with some intermixture of shingle and stones (sandy foreshore). In relation to tides, they can be divided into lower shores (beneath water more than half the time) and upper shores (above water more than half the time). The lower shore is characterized by marine species, whereas the upper shore is characterized by terrestrial species which tolerate being regularly covered by seawater (Kålås et al. 2010). Some biotopes covered with herbaceous vegetation situated on the upper shore may partly overlap with coastal meadows and salt marshes (see 2.3.16).

We denoted these biotopes from the interpretation of the satellite images. They have very distinctive shape and a "murky" pink color with gray or whitish shades. Also their topographical situation is very specific. In the images Landsat TM/ETM+, with the standard combination of fusion channels, sandy beaches and coastlines are characterized by a bright light which indicates bare or nearly bare surface (pink, whitish), or by yellow-green, blue and green colors, which indicate meadow vegetation. Shallow water and inter-tidal rocks which become dry during ebbs are characterized by muddy-pink, gray or whitish hues. Their colours clearly contrast with the adjacent deep water. Dry rocks on the coast have blue-green or pinkish-white colors. Some errors in the delineation of all these areas may be due to the unknown level of the tide at flood, which has been fixed on satellite images. To reduce the likelihood of such errors, we tried wherever possible to compare images taken at different times of the day with different levels of sea water.

2.3.24. Stratified lakes

Stratified lakes are those whose water is in non-miscible layers. The types of stratification and the reasons for the phenomenon may vary. Temperature stratification – also called the thermocline – consists of layers of water each at a different temperature. This is observed at particular periods of the year in almost all waters of sufficient depth. The other type of water stratification is chemical, consisting of layers containing different concentrations of dissolved salts. Only stratified lakes of the latter type were selected and mapped in this study. These lakes are also called meromictic lakes (Findenegg 1937).

Usually in meromictic lakes, the difference in salinity of the water layers in a vertical direction creates a vertical density gradient. Owing to this, the denser lower layers do not mix with the upper layers for years or even decades. This causes the formation of anoxic conditions in the lowest layer of undisturbed water. The boundary between the oxygenated water layers and the anoxic layer of deep water is called the chemocline.

These layers, different in physical and chemical conditions, provide a variety of ecological niches that are inhabited by different species of animals, plants and micro-organisms. The Black Sea is the best known meromictic lake in Europe but is outside the study area, where the only meromictic lake, the relic Mogilynoye Lake on Kildin Island in the White Sea, is situated in **Murmansk Region**. Kildin Island is separated from the Kola Peninsula by the long, narrow Kildin inlet. Mogilynoye Lake is a small watershed about 0,5 kilometer in length, which was separated from the sea by a low ridge 60-70 m in width after the lifting of the sea shores about one thousand years ago. This unique lake has five stratified layers, each harboring its own specific group of organisms (Deryugin 1925). As a result of evolutionary adaptation to these particular environmental conditions, several species of marine organisms (e.g. *Astarte borealis*, *Goniocarpa coriacea*, *Tethyum rusticum)* are characteristically much smaller than in the adjacent sea areas. Some species (e.g. *Terpios fugax, Caesira nana, and C. ampulloides),* are probably extinct from the Murman coast of the Barents Sea, but still exist in Mogilynoye Lake. The Kildin cod (*Gadus morhua kildinensis*) is included in the Red Data Book of the Russian Federation (2000).

2.3.25. Salmon spawning sites

The most universal criterion for the selection of valuable aquatic biotopes is whether the biotope is a key habitat for hydrobionts, chiefly for fishes, during their breeding seasons. Fishes usually make migrations of varying lengths and the locations of their spawning grounds occupy only a small fraction of the total area in which they may occur. Salmon spawning sites are often in vulnerable aquatic habitats which are in need of protection regardless of the fact that they are also spawning sites. In addition, some aquatic biotopes serve as habitats for rare and endangered species of fishes and other hydrobionts. Terrestrial biotopes like forests, mires, or meadows have been relatively well studied, but the biodiversity of aquatic habitats has no such study tradition. Aquatic habitats are often investigated only for the purposes of fisheries management.

Salmon or salmonid spawning places are especially valuable. The Atlantic salmon (*Salmo salar*), including its freshwater form (*Salmo salar* morpha *sebago*), and brown trout (*Salmo trutta*) spawn only in those parts of rivers with clear water, fast current and a stony bottom without sludge. Such sites are not only habitats for spawning, but also habitats for salmon fishes at their juvenile stages. In fishery terms these sites are called not "spawning" but "spawning and growing" areas. In addition to salmonids, these areas are important for the existence of a number of other rare, threatened and valuable fish like grayling (*Thymallus thymallus*) and sculpin (*Cottus gobio)*, etc., as well as for lamprey (*Lampetra fluviatilis*) and molluscs like the freshwater pearl mussel (*Margaritifera margaritifera*) and the thick-shelled river mussel *(Unio crassus).* In contrast with salmonids, these species live here permanently. These biotopes are also inhabited by several rare species of birds including the dipper (*Cinclus cinclus*) and kingfisher (*Alcedo althis*); by mammals such as the otter (*Lutra lutra*) and the European mink (*Mustela lutreola*); as well as by many insect species including stoneflies (Trichoptera), mayflies (Ephemeroptera), and dragonflies (Odonata). Many of them are red listed. Depending on the nature of the soil, water flow velocity, depth, and chemistry among other factors, various combinations of associated species are formed in such habitats. Streams of different sizes, ranking from small brooks about 1 meter to deep rivers up to hundreds of meters in width, are suitable sites for spawning salmon. Typically, small streams and rivers are more suitable for trout, whereas the Atlantic salmon prefers the larger ones, although the boundary between large and small streams varies. In fact, there are numerous rivers in which both species occur together.

Nearly all rivers in which salmon or trout occur can be considered rivers with conservation value. They meet several criteria for HCV areas, e.g. minimal disturbance, natural key habitats of animals during the breeding and migration periods, habitats for threatened and rare species, high biodiversity, and influence on natural systems outside these biotopes or their complexes.

In the 20th century, during the period of intensive development of northwest Russia, many rivers either totally lost their role as salmon spawning sites or the number of spawning fish declined drastically. The main reasons include building of dams for hydropower stations, pollution caused by pulp and paper mills, and destruction of natural spawning areas by sunken timber, the result of vast-scale timber floating in the rivers.

We selected spawning areas using the following sources:

- field investigations by regional experts
- literature sources
- the Rules of Fisheries, which are established for different fishery regions (the fisheries basins).

We used data for the northern fishery basin, which includes the entire study area. This document contains lists of water bodies, rivers and lakes where fishing is restricted due to the presence of spawning sites of salmonids and other valuable fish species.

Spawning rivers were mapped completely, without specifying the individual sites which contain rapids. This was done firstly because rapids are often evenly distributed along the river bed. Second, we tried to emphasize the fact that a HCV area incorporates the entire river, rather than individual stretches, because the most valuable sites can not be preserved in isolation. They can maintain their natural functions only in the case of preserving the entire channel.

In **Leningrad, Vologda** and **Murmansk Region**s this type of HCV area has been selected and mapped on the basis of the results of field inventories by local experts. For Murmansk Region, we selected only spawning rivers of the Atlantic salmon because trout is widely distributed there, and all streams where it occurs could not be considered as objects of special conservational value. In **Arkhangelsk Region** and **the Republic of Karelia**, we used only the lists of spawning rivers obtained from the official Rules of Fisheries.

2.3.26. Bird colonies on sea coasts

Steep cliffs create biotopes suitable for seabird colonies, the massed nesting of species including auks (Alcidae), gulls (*Larus*), shorebirds (Charadriidae), albatrosses (Tubinares), cormorants (*Phalacrocorax*), ducks (Anatidae), gannets (*Morus*), etc. (Biological Encyclopedic Dictionary 1986). According to Belopolsky (1957), their conservational value derives from three main factors:

1. Sea birds that live in colonies play a significant role in marine ecosystems.
2. Seabird colonies are usually confined to areas which have high biological productivity. In this regard, the dynamics of the seabird colonies is a good monitoring indicator of the state of the environment in these areas.
3. Nesting places of several rare species of sea birds are often confined to seabird colonies.

In this study, seabird colonies have been selected and mapped only in **Murmansk Region**. We selected only colonies of more than 200 nesting pairs or more than 30 pairs of species included in the Red Data Book of the Russian Federation. In addition to the previously known colonies we have also mapped several sites known from the literature (Bakken 2000) or from data collected by means of interviews with local people, hunters, bird-watchers and others during the last five years and confirmed by a qualified researcher. Because of their small size, seabird colonies were marked on the map by a point placed approximately in the center of the colony. Two or more colonies situated on the same island and less than 1 kilometer from each other were mapped as a single HCV area. Colonies formed by shorebirds and ducks only were not selected because this is not the principal pattern of nesting for these species.

2.3.27. Important Bird Areas in Russia

Important Bird Areas in Russia are key sites that are critical as habitats for nesting, molting, wintering and stop-over during migrations. The selection of them is considered a particularly effective way of identifying conservation priorities. Important Bird Areas in Russia are key sites for conservation, small enough to be conserved in their entirety and often already part of a protected areas network. According to the definition of the Russian Bird Conservation Union (http://rbcu.ru/programs/77/3388), they include:

- habitats for one or more globally threatened species
- habitats for a relatively high number of rare and vulnerable species (subspecies, populations), including those listed in the IUCN Red List and Red Data Book of the Russian Federation
- a set of habitats that together hold a suite of restricted-range species or biome-restricted species
- a set of habitats that together hold a suite of restricted-range species or biome-restricted species
- places of formation of large nesting, wintering, molting and migrating flocks of birds.

Criteria for Important bird areas for the European part of Russia were drawn up by the Russian Bird Conservation Union based on international criteria of BirdLife International (http://rbcu.ru/kotr/crit_eu.php). The Important Bird Areas in Russia database is maintained by the Russian Bird Conservation Union. The members of this organisation constantly update this database according to a standard format (http://rbcu.ru/kotr/cheme_eu.php).

By courtesy of the Russian Bird Conservation Union, we had at our disposal the database containing mapping data on the spatial location of the important bird areas of international importance in the European part of Russia, dated May 31, 2009, with the boundaries of 68 important bird areas in the study area in electronic format. We have displayed contours of all Important Bird Areas in Russia directly using this information, without any modifications.

2.3.28. Habitats of plant, lichen and fungus species included in Red Data Book of Russian Federation

The study of the vegetation of northwest Russia has a long history. There are many publications recording the discovery of species presently included in the Red Data Book of the Russian Federation (2008). The most comprehensive data concerning specimens collected during approximately the last 150 years and preserved in the herbaria of the Komarov Botanical Institute of the Russian Academy of Sciences (St. Petersburg), are presented in the four volumes of the Flora of the North-East European part of USSR (Flora…1974-1977). Numerous herbarium samples collected during the same period but now housed in herbaria of West European countries are presented in the classical account by E. Hultén, "Atlas of the distribution of plants in Northern Europe" (Hultén 1971). Both of these basic publications also include all literature records, including both Russian and western references, which were known at the moment of writing. These publications contain dot maps of plant, lichen and fungus species in Arkhangelsk Region, the Republic of Karelia and many areas within the other administrative regions of northwest Russia. These data could not be entirely included in this study due to difficulties with the exact indication of the collecting places, but those records which have been confirmed by the findings of the regional experts have been selected and mapped, and the exact coordinates of findings of the species included in the Red Data Books were obtained using GPS navigators. In **Arkhangelsk, Murmansk, Leningrad** and **Vologda Regions**, however, we selected and mapped localities where rare and threatened species of plants, lichens and fungi were recently recorded during preparation work of the regional Red Data Books and some other publications on the distribution of rare and threatened species (see below).

Generally, the flora of the most of the regions included in this study has been unevenly studied. The majority of the known collecting places and the characteristics of the habitats of rare and threatened species are reported from protected areas and their surroundings. In contrast, in some parts of northwest Russia there are still large areas which are totally unstudied in terms of species composition of plants, lichens and fungi, and data on the distribution of species included in the Red Data Book of the Russian Federation are insufficient. In other words, the available data on the distribution of these species in protected areas and other well-studied areas do not necessarily reflect their actual distribution in northwest Russia from a broader perspective. Thus, the reader should be aware that the absence of the sign “habitat of species included in the Red Data Book of the Russian Federation” in the maps does not mean that this species is absent there, but may be due to insufficient information. The urgent aim of this study was to discover the presence of rare and threatened species in possible HCV areas to prevent the threat of anthropogenic disturbance.

The Red Book of the Russian Federation is the basic scientific and administrative document regulating plant conservation in Russia. In this study, we selected and mapped locations of the collection places with indication of the ecological characteristics of the habitats only for those species that are included in the list of species approved by the Russian Ministry of Natural Resources on October 25, 2005 № 289: “On the approval of the lists of objects of flora (vascular plants, mosses, lichens and fungi) included in the Red Book of the Russian Federation and excluded from it on June 1, 2005” (Regulation N 289… 2005).

Article 60 of the Federal Law “On Environmental Protection” dated 10.01.2002; № 7-FZ (Federal Law on Environmental Protection…2002), states: “Plants, animals and other organisms belonging to the species listed in Red Data Books must be excluded from economic use everywhere in the territory of the Russian Federation. All activities leading to reduction in the numbers of these species of plants, animals and other organisms and deterioration of their habitats are prohibited”.

Although species included in the Red Data Book of the Russian Federation and their habitats are entitled to special protection throughout the whole country, the procedure for protection of the species included in the regional Red Data Books is always modified by regional legislation. In the majority of regions, the protection regimes for these species are not clearly prescribed. Therefore, we decided to select and map only a limited list of species which are included in the list of October 25, 2005 (Regulation N 289… 2005) , hereafter “red-listed species”. According to federal law, all these species as well as their habitats are protected in all regions of the Russian Federation regardless of regional modifications in nature protection legislation. A list of these species and information on their presence in the studied areas are shown in Table 2.7. The main sources of information regarding the species included in the list of October 25, 2005 are shown in Table 2.8.

On the final maps, collecting places of the red-listed species are given according to their categories accepted in the Red Book of the Russian Federation (2000, 2008), namely:

0 – Species which are probably regionally extinct;
1 – Endangered species, drastically declined in population size with restricted distributional area;
2 – Vulnerable species, declined in population size and distributional area;
3 – Rare species;
4 – Species with uncertain status but suspected to be threatened;
5 – Species which have been successfully re-established.

These categories are, in fact, equivalent to the former IUCN (1993) categories, but do not fully coincide with the modern IUCN (2001) categories. The latter are mentioned in some regional Red Data Books published after 2001, but in practice the former IUCN (1993) categories are used everywhere.

In **Leningrad Region** and the **City of St. Petersburg**, we mapped all the localities where the findings of the red-listed species were confirmed by the regional experts, both on the mainland and on the aquatoria of the Baltic Sea. Numerous data were obtained in 1998-2010 during the inventory work aimed at the establishment of new protected areas, preparation of the regional red lists: Red Data Book of Nature of the Leningrad Region (1999, 2000, 2002) and Red Data Book of Nature of the City of St. Petersburg (2004), and the implementation of the project “Gap analysis in northwest Russia”. All these research studies were supported by Russian-Finnish cooperation in biodiversity conservation and creation of protected areas in the Leningrad Region and St. Petersburg. Field inventories on a vast scale were undertaken by the regional experts and the exact geographical coordinates (to within 200 m) of the collecting places of the red-listed species were obtained using GPS navigation. Additional information was obtained from the study of the herbarium samples in St. Petersburg (see Table 2.8), and from data published in regional red lists. In some cases, we used information from more recent publications. Data on the Karelian Isthmus and on the neighborhood of the river Svir, contained in the atlas by E. Hultén (Hultén, 1971), are taken into account only if they have been subsequently included in the regional red lists. The precise locations of collecting places on the basis of the literature, without confirmation by the regional experts, may err by several kilometers.

In **Vologda Region** we mapped all collecting places of red-listed species of plants, lichens and fungi which are indicated in the Red Data Book of the Vologda Region (2004). Many of these findings were made quite recently, during preparation work on the regional red list. The data for mapping were obtained from three sources: (1) field inventories by the regional experts where coordinates were obtained using GPS navigators or from precise identification by the collector, (2) oral reports about the findings by other people, with exact indication of the localities, and (3) published data. The accuracy of identification of the find localities depends on the source. There are a number of references which have been used in this study only partially, to the extent to which they are included in the Red Data Book of Vologda Region (2004). They include, for instance, the lists of vascular plants from the southern shores of Lake Onega included in Hultén’s account (Hultén 1971) and more recent lists of vascular plants of the Darwin Strict Nature Reserve, National Park Russian North and the protected nature complex “Onega” established in 2009 (Alexey Kravchenko, pers.comm).

In **Arkhangelsk Region** we used only published sources, namely the Red Data Books of the Region (Red Data Book of the Arkhangelsk Region 1995, 2008). Dot distribution maps of plant species contained in the volumes of the Flora of the North-East European part of USSR (Flora…1974-1977), are applied only to the extent to which they are included in the regional red lists. The accuracy of the positions of the localities here is not very high.

In **Murmansk Region**, vice versa, we chiefly used the data resulting from field inventories by regional experts, primarily from Polar-Alpine Botanical Garden & Institute of Kola Research Center of Russian Academy of Sciences (Apatity), and the NGO Kola Biodiversity Conservation Center (Murmansk) and its partners. The coordinates of all the collecting places were obtained with GPS navigators, or specified by the collectors on topographic maps of scale not less than 1: 200,000. Only a small number of findings, mainly for remote areas that have not been covered by field inventories in recent years, are indicated on the basis of the study of the herbaria and literature. Dot distribution maps of plant species contained in the Flora of the Murmansk Region (1953-1966) were applied only to the extent to which they are included in the Red Data Book of Murmansk Region (2003).

In **the Republic of Karelia** we used only data obtained by regional experts from the NGO SPOK, in which the coordinates of all the collecting places of the red-listed species were recorded using GPS navigation. In addition, we used the results of a study of the distribution of the family Orchidaceae (Markovskaya 2004). Other literature on the distribution of the red-listed species of plants, lichens and fungi, although substantial, e.g. Hultén (1971), Kravchenko & Kuznetsov (1995, 2008), Kravchenko (2007), Red Data Book of the Republic of Karelia (1995, 2007), etc., were unfortunately not taken into account. Therefore, in Chapter 3, the distribution of the red-listed species in protected areas is not analyzed because of lack of representativeness in comparison with other regions. The data presented on the maps do not reflect the actual distribution of these species in the Republic of Karelia. For more information on the distribution of the red-listed species of fungi, we recommend Bondartseva et al (2000), Krutov et al. (2009), Shubin & Predtechenskaya (2009); on the lichens, Fadeyeva et al. (2007), Fadeyeva (2009); on the mosses, Maximov (2009); and on the vascular plants, Kravchenko (2007), Kravchenko & Kuznetsov (2009).

The accuracy of the positions of plant collections shown by the herbarium labels and in the literature is very variable. It may depend on the collector, on the rules adopted in a particular historical period, and on purely geographical reasons, for example, on the presence of a well-known or well-marked topographical landmark nearby. Very often, the labels are not written in accordance with conventional standards, e.g. not all the fields required for accurate mapping of the collecting place are filled in. Handwritten labels may be hardly readable. Generally, the accuracy of identifying collecting places in botanical research was often quite low until the appearance of satellite navigation systems (GPS), and the errors may be significant. In addition, the geographical names mentioned in the old publications may be very different from the current ones. The only exceptions are the labels confined to objects well marked on maps, e.g. the tops of mountains, the confluence points of rivers, etc. This shows a need for unification of the procedures of mapping using data which are not GPS-confirmed. Below we describe the methods used for searching the locations of the collecting places indicated in the labels at the herbarium collections. The term "location" below means the geographic location of the collecting place of the species, the term "habitat" means the ecological characteristics of the collecting place of the species.

Case 1. The collection place of the species is situated within an object of small extent which is well marked on the map (i.e. "reference object" below) or in its immediate vicinity (i.e. the label includes words "near", "close", "next to", etc.). In this case, we mapped the location of the collection place of the species within the boundaries of this object, if the nature of the object does not contradict nowadays either the environmental demands of the species, or the habitat type indicated on the label. If the habitat type is not specified on the label, we used the literature on the ecology of this species. If the present characteristics of the reference object show that the species cannot inhabit this place (for example, the collecting place for a terrestrial species appears to be under water), we used coordinates of the nearest suitable habitat for the species. If the collection place is indicated on the label by words such as "near", "close", or "next to", we placed the point in the center of suitable habitat within a radius of 100 meters. If a suitable habitat can not be found (for example, due to anthropogenic transformation of the area since the collecting of the species), we placed the point in the centre of the reference object, even if the presence of the species in the reference object at the moment of writing seems doubtful due to the absence of suitable habitats.

Case 2. The collection place of the species is indicated on the label by the direction and distance from the reference object which is indicated on the map (e.g. settlement, mountain top, etc.). In this case, we mapped the location of the collection place corresponding to the direction and the distance from the center point of the reference object, if it does not contradict the environmental demands of the species. If the location found following the direction and distance indicated on the label is not suitable for the species, we mapped the proposed point of the collecting place in the nearest suitable habitat within a radius of 500 meters. If suitable habitat within a radius of 500 m can not be found, the point of the collecting place is placed directly in the centre of the reference object. This method of indicating collection places is notoriously inaccurate but it was the only way to show old collecting places of species not covered by recent field investigations.

Case 3. The label has no indication of the exact reference object, but the collection place of the species is presented as a "neighbourhood" of a relatively large object like a city, village, mountain, lake, etc. If the reference object is a settlement, we mapped the point of the collection place of the species in the nearest suitable habitat within 1 km of the border of the settlement. Where suitable habitat was absent we placed the point of the collecting place within 1 km of the center of the reference object, regardless of its suitability for the species.

Case 4. There is no exact indication of the reference object on the label, but the collecting place is presented vaguely, for example, "the lower reaches of the river N". In such cases, we did not follow any general rule. If the area is relatively small and an appropriate biotope can be found there, we indicated that as a key habitat and the possible collecting place. This approach seems suitable to species with strict ecological demands since they occur only in a very restricted set of the key habitats. In addition, the labels often contain some indirect information which could be used as indicators of the habitat type. For example, if the label says that the species has been collected "near the stream" and additionally mentions "the meadow", we can assume that the collecting place was somewhere in the lower reaches of the stream. If no suitable habitat was found in the area indicated on the label, we assigned the possible collecting place approximately, for example next to the name of the river in its lower reaches. If the area indicated on the label is too large for a detailed review, we did not map the collecting place. However, if a species is confined to some very specific habitats which are rare in this area, we tried to discover and map them. The collection place of the species was placed near to the geometric centre of these habitats.

Table 2.7. Presence of plant, lichen and fungus species included in the Red Data Book of the Russian Federation (2008) in different regions of the study area.

•- Species present in the area and records have been mapped in this study

• (red) - Species present in the area but records have not been mapped in this study

Species	Category in Red Data Book of Russian Federation	Presence of the species in the area					
		St. Petersburg	Leningrad Region	Vologda Region	Arkhangelsk Region	Murmansk Region	Republic of Karelia
Fungi							
Boletopsis leucomelaena (Pers.) Fayod	3		•				• (red)
Ganoderma lucidum (W. Curt.: Fr.) P. Karst.	3	•	•				• (red)
Geastrum fornicatum (Huds.) Hook.	3		•				
Grifola frondosa (Dicks.: Fr.) Gray	3	•		•	• (red)		
Polyporus umbellatus (Pers.) Fr.	3			•			
Sarcosoma globosum Schmidel) Rehm	2		•		• (red)	•	
Tricholoma colossus (Fr.) Quél	2	•	•				
Lichens							
Bryoria fremontii (Tuck.) Brodo et D. Hawksw.	3		•	•	•	•	•
Lichenomhpalina hudsoniana (H. S. Jenn.) H. E. Bigelow	3					•	• (red)
Lobaria pulmonaria (L.) Hoffm.	2	•	•	•	•	•	•
Menegazzia terebrata (Hoffm.) A. Massal.	3		•		• (red)		• (red)
Stereocaulon dactylophyllum Flörke	2		• (red)			• (red)	• (red)
Tuckneraria laureri (Kremp) Randlane et Thell	3		• (red)				• (red)
Usnea florida (L.) Weber ex F.H. Wigg.	2			•			

Species	Category in Red Data Book of Russian Federation	Presence of the species in the area					
		St. Petersburg	Leningrad Region	Vologda Region	Arkhangelsk Region	Murmansk Region	Republic of Karelia
Bryophytes							
Aulacomnium androgynum (Hedw.) Schwaegr.	3		•				
Cryptothallus mirabilis Malmb.	3		•			•	•
Lophozia decolorans (Limpr.) Steph. [*Isopaches decolorans* (Limpr.) Buch]	3					•	
Nardia breidleri (Limpr.) Lindb.	3					•	
Scapania sphaerifera Buch et Tuomik.	2					•	
Sphagnum molle Sull.	2						•
Tortula lingulata Lindb.	3		•				
Vascular plants							
Ajuga pyramidalis L.	2		•				
Aldrovanda vesiculosa L.	3		•				
Alisma wahlenbergii (Holmb.) Juz.	1	•	•				
Armeria vulgaris Willd.	3		•				
Arnica alpina (L.) Olin [*Arnica fennoscandica* Jurtzev et Korobkov]	2				•	•	
Beckwithia glacialis (L.) A. et D. Love	3					•	
Botrychium simplex E. Hitchc.	2		•				•
Calypso bulbosa (L.) Oakes	3		•	•	•	•	•
Carex davalliana Smith	1		•				
Carex umbrosa Host	3		•				
Caulinia flexilis Willd.	2		•				•
Caulinia tenuissima (A.Br. ex Magnus) Tzvelev	1	•	•				
Cladium mariscus (L.) Pohl	2		•				
Cotoneaster cinnabarinus Juz.	3					•	•
Cypripedium macranthon Sw.	3			•			
Cypripedium calceolus L.	3	•	•	•	•	•	•
Dactylorhiza baltica (Klinge) Orlova	3	•	•	•	•		•
Dactylorhiza traunsteineri (Saut.) Soo s.l.	3	•	•	•	•	•	•
Epipogium aphyllum Sw.	2		•	•	•	•	•
Gypsophila uralensis Less. ssp. *pinegensis* (Perf.) Kamelin	3				•		
Helianthemum arcticum (Grosser) Janch.	1					•	
Isoëtes lacustris L.	3	•	•	•	•	•	•
Isoëtes setacea Durieu	2	•	•	•	•	•	•
Liparis loeselii (L.) Rich.	2		•				•
Littorella uniflora (L.) Asch.	2		•				•
Lobelia dortmanna L.	3		•	•	•	•	•
Myrica gale L.	2	•	•				•
Ophrys insectifera L.	2		•	•			•
Orchis militaris L.	3	•	•	•	•		
Orchis ustulata L.	2		•				
Papaver lapponicum (Tolm.) Nordh.	3					•	
Pulsatilla pratensis (L.) Mill.	3		•				

Species	Category in Red Data Book of Russian Federation	Presence of the species in the area					
		St. Petersburg	Leningrad Region	Vologda Region	Arkhangelsk Region	Murmansk Region	Republic of Karelia
Pulsatilla vernalis (L.) Mill.	2		•				•
Pulsatilla vulgaris Mill.	1		•				
Rhodiola rosea L.	3				•	•	•
Rhynchospora fusca (L.) *Ait. fil.*	3		•				•
Silene rupestris L.	2		•			•	•
Swertia perennis L.	1		•	•			
Taraxacum leucoglossum Brenn.	1					•	
Tillaea aquatica L.	3	•	•				•

Table 2.8. Sources of information used in mapping collecting places of red-listed species of plants, lichens and fungi.

Region	Sources of information	
	Herbaria (acronyms are given after Index Herbariorum), and references	**Findings by regional experts**
Leningrad Region and St. Petersburg	Herbaria: LECB, LE, H. References: Alekseeva & Himelbrandt (2007), Glazkova (2006), Doronina (2007), Konechnaya (2006), Kotkova (2007), Kurbatova (2007), Kurbatova & Doroshina-Ukrainskaya (2005), Leushina & Kurbatova (2006), Tsvelev & Glazkova (2007), Kuznetsova et al. (2007).	Vascular plants: G. Yu. Konechnaya, N. N Tsvelev, A. Yu. Doronina, P. G. Yefimov, I. A. Sorokina, E. A. Glazkova, I. D. Illarionova, L. I. Krupkina, V. I. Dorofeev, V. I. Byalt, V. V. Geltman, I. O. Buzunova, E. A. Volkova. Bryophyta: E. N. Andreeva, L. E. Kurbatova. Lichens: E. S. Kuznetsova, D. E. Himelbrandt, I. S. Stepanchikova, N. M. Alekseeva, L. A. Konoreva. Fungi: V. M. Kotkova.
Vologda Region	Herbaria: *H, LE, LECB, MW, IBIW, PTZ, SYKO*, Darwin Strict Nature Reserve, Vologda State Pedagogical University. References: Red Data Book of Vologda Region (2004).	Vascular plants: T. A. Suslova, A. B. Chobadze, A. N. Levashov, V. I. Antonova. Lichens: A. B. Chobadze.
Arkhangelsk Region	References: Red Data Book of Arkhangelsk Region (1995, 2005).	–
Murmansk Region	Herbaria: Polar-Alpine Botanical Garden & Institute of Kola Research Center of Russian Academy of Sciences, MHA, LE. References: Flora of Murmansk Region (1953-1966), Ramenskaya (1983); Red Data Book of Murmansk Region (2003), Konstantinova, ed. (2009).	Polar-Alpine Botanical Garden & Institute of Kola Research Center of Russian Academy of Sciences, NGO Kola Biodiversity Center, The Nature Protection Group of Faculty of Biology of the Moscow State University, Botanical Institute of Russian Academy of Sciences, and personal observations by G. N. Aleksandrov, K. N. Kobyakov, D. B. Koltsov, L. A. Konoreva, N. A. Konstantinova, V. A. Kostina, A. D. Kozhevnikova, V. N. Petrov, O. V. Petrova, M. Y. Plets, T. V. Philimonova, A. V. Razumovskaya, D. Yu. Smirnov.
The Republic of Karelia	Herbaria: *PZV, PTZ, MW, MHA, MOSP, H.* References: Kuznetsov (1993), Dyachkova (1998)	Vascular plants: N. V. Markovskaya Lichens: V. N. Tarasova, V. I. Androsova

2.3.29. Habitats of animal species included in Red Data Book of Russian Federation

We include in the analysis the species of mammals, birds, fish, cyclostomes, insects, and bivalves which are included in the Red Data Book of Russian Federation (2000). Many of these species are exposed to direct threats such as hunting, fishing and collecting; others are sensitive to disturbance, or are confined to habitats which are easily disturbed in the process of economic activities. Conservation to meet their habitat requirements needs special protection regimes which are possible only in specially protected natural areas.

We used a list of species defined by the Regulation of the State Committee on the Ecology of the Russian Federation (Goskomecologia) of 19.12.1997, № 569, updated on 09.09.2004: "On the approval of the lists of objects of fauna (animals: vertebrates and invertebrates) included in the Red Book of the Russian Federation" (Regulation N 569…1997).

The distribution of habitat types of the red-listed species of animals in all areas included in this study has been very unevenly studied. As in the case of plants, the best studied areas are strict nature reserves, national parks and the surroundings of biological research stations. In addition, it is necessary to take into account the mobility of animals which, depending on various factors both anthropogenic and natural, can change their places of habitation, and are not necessarily found each year in the same place. Thus, the data on the habitats of the red-listed species presented in this study are limited to the available information sources and can not be considered as complete.

In **Leningrad Region** and the city of **St. Petersburg**, most of the data were obtained in 1998-2010, during the inventory work aimed at the establishment of new protected areas, the preparation of the regional red lists and the implementation of the project "Gap analysis in northwest Russia". All these research studies were supported by Russian-Finnish cooperation in biodiversity conservation and the creation of new protected areas in Leningrad Region and St. Petersburg. All the data were provided with exact geographical coordinates obtained using GPS navigation. The authors of these unpublished data for birds are: Yu. G. Boyarinova, A.R. Gaginskaya, N.P. Iovchenko, S.A. Kouzov, G.A. Noskov, V.G. Ptchelintsev, T.A. Rymkevich, O.P. Smirnov and D. A. Starikov; for fishes: I.Yu. Popov. Other sources of information are numerous materials published in the regional red lists, the Red Data Book of Nature of Leningrad Region (2002) and the Red Data Book of Nature of St. Petersburg (2004). We mapped the localities of the findings of the red-listed species both on the mainland and on the aquatoria of the Baltic Sea. The accuracy of the locations of red-listed species finds was verified by the authors of the species descriptions in these regional red lists.

In **Vologda Region,** we mapped localities where red-listed species were found during recent preparation work on the regional red list, the Red Data Book of Vologda Region (2010). The data for mapping were obtained from three sources: field inventories of the regional experts (GPS- navigation, and/or the exact indication of the reference objects); oral reports from local people about findings of the red-listed species; and published data.

In **Arkhangelsk Region,** we used only published sources, namely the Red Data Books of Arkhangelsk Region (1995, 2008). The information was transferred from the maps presented in these publications and the accuracy of the spatial referencing of these data is relatively low.

In **Murmansk Region**, we mapped only the nesting sites of red-listed species of birds and the breeding colonies of seals. These places usually have distinct boundaries and most of them are perennial habitats. Also, we mapped the only known and clearly localized habitat of the Kildin cod. As sources of information we used the results of field inventories conducted by experts from the NGO Kola Biodiversity Center, and personal observations by numerous experts, viz.: G.N. Aleksandrov, V.V. Byanki, Yu. M. Bytchkov, S.A. Ganusevich, S.A. Dylyuk, A.V. Yezhov, K.N. Kobyakov, M.L. Kreindlin, V.N. Petrov, M.Y. Plets, and E. O. Potorochin. Data published in the Red Data Book of Murmansk Region (2003) were used mainly for mapping of well-known long-term habitats of red-listed species in remote areas that have not been covered by field inventories during recent years.

In **the Republic of Karelia**, we used only data for birds obtained from field surveys on the territories of the proposed protected areas, conducted by experts from the NGO SPOK. Additional observations on the red-listed species of birds were obtained from a Finnish researcher, Veli-Matti Sorvari.

Table 2.9. Presence in different regions of the study area of animal species included in the Red Data Book of Russian Federation (2000).

•- Species present in the area and records have been mapped in this study

• (red) - Species present in the area but records have not been mapped in this study

Species	Category in Red Data Book of Russian Federation	Presence of the species in the area					
		St. Petersburg	Leningrad Region	Vologda Region	Arkhangelsk Region	Murmansk Region	Republic of Karelia
Mammals							
Desmana moschata (L.)	2			•			
Halichoerus grypus ssp. *grypus* (Fabricius)	3					•	
Halichoerus grypus ssp. *macrorhynchus* Hornschuch and Schilling	1		•		• (red)		
Phoca hispida ssp. *botnica* (Gmelin)	2	•	•				
Phoca hispida ssp. *ladogensis* (Nordquist)	3		•				• (red)
Phoca vitulina (L.)	3				• (red)	•	
Birds							
Anser erythropus (L.)	2	•	•	•		•	• (red)
Aquila chrysaëtus (L.)	3		•	•	•	•	•
Aquila clanga Pallas	2		•	•	•		•
Aquila pomarina Brehm.	3		•	•			• (red)
Aythya nyroca (Guldenstadt)	2		•	•			
Bubo bubo (L.)	2	•	•	•	•		•
Calidris alpina ssp. *schinzi* (L.)	1		•				
Ciconia nigra (L.)	3		•	•			• (red)
Circaetus gallicus (Gmelin)	2		•	•			• (red)
Cygnus bewickii Yarr.	5			•	• (red)	• (red)	• (red)
Falco peregrinus Tunst.	2		•	•	• (red)	•	•
Falco rusticolus Gmelin	2		•	•	• (red)	•	
Gavia arctica ssp. *arctica* (L.)	2		•	•			•
Haematopus ostralegus ssp. *longipes* (Buturlin)	3		•	•			• (red)
Haliaeetus albicilla (L.)	3	•	•	•	•	•	•
Hydroprogne caspia (Pallas)	3		•				• (red)
Lagopus lagopus ssp. *rossicus* Serebrovsky	2	•	•	•			
Lanius excubitor L.	3		•	•	• (red)	•	•
Numenius arquata (L.)	2	•	•	•			
Pandion haliaetus (L.)	3	•	•		•	•	•
Parus cyanus cyanus (Pallas)	4		•	•			• (red)
Phalacrocorax aristotelis (L.)	3					•	
Pluvialis apricaria ssp. *apricaria* (L.)	3		•	•			
Sterna albifrons Pallas	2	•	•	•			• (red)
Fishes and Cyclostomata							
Acipenser sturio (L.)	0	•	•	•			• (red)
Alburnoides bipunctatus ssp. *rossicus* Berg	2			•			
Alosa fallax ssp. *fallax* (Lacepède)	4		•				
Coregonus lavaretus ssp. *baeri* Kessler	2		•				
Cottus gobio (L.)	2	•	•	•			
Gadus morhua kildinensis Berg	1					•	

Species	Category in Red Data Book of Russian Federation	Presence of the species in the area					
		St. Petersburg	Leningrad Region	Vologda Region	Arkhangelsk Region	Murmansk Region	Republic of Karelia
Petromyzon marinus (L.)	1		•				
Salmo salar morpha *sebago* Girard	2		•	•			•
Salmo trutta ssp. *trutta* Berg	2	•	•	•			•
Stenodus leucichthys nelma (Pallas)	1			•	•	•	•
Thymallus thymallus (L.) (populations living in the rivers which belong to the Volga river basin)	2			•			
Molluscs							
Margaritifera margaritifera (L.)	2	•	•	•	•		•
Insects							
Aphodius bimaculatus (Laxmann)	2		•				
Anax imperator Laech	2		•				
Carabus menetriesi Hummel	2	•	•	•			•
Osmoderma eremita (Scopoli)	2		•				
Orussus abietinus (Scopoli)	2		•				
Otiorhynchus rugosus (Hummel)	1	•	•				•
Parnassius apollo (L.)	2			•			•
Parnassius mnemosyne (L.)	2	•	•	•	•		•
Xylocopa valga Gerstaecker	2		•		•		

The Clouded Apollo *(Parnassius mnemosyne)* appears rarely and only in natural grasslands, usually on shores of rivers and lakes. Category 2 in Red Data Book of Russian Federation. Photo: Andrey Humala.

Intact herb-rich spruce-mire in boreal forest of Maksimjärvi area. Planned zakaznik Spokoyny, Republic of Karelia. Photo: Jyri Mikkola.