Sketches of Russian Mires

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Introduction

Russia is not commonly associated with mires. In countries such as Finland or Ireland, mires cover a greater proportion of the country's territory and play a more significant role in its social and economic life. In Russia, mires cover about 8% of the country's area, and, together with paludified lands, account for 20% of its territory (VOMPERSKY et al. 1999). However, there are few places in the world where one finds such a high diversity of mire types and biogeographical variations.

Mire distribution is distinctly connected with bioclimatic zones and subzones. Optimum conditions for paludification are reached when there is equilibrium between conditions suitable for high production on one hand (high humidity and temperature), and low destruction on the other (high humidity, but low temperature). This situation is typical for Russia's boreal zone, where, in some regions, mires cover over 50% of the land surface (Fig. 1). All possible combinations of geomorphologic, climatic, and paleogeorgaphic factors across the territory of Russia, the world's largest country, result in great variation of mire types.

Mires became a part of land use and culture in many regions, and objects of thorough interest for different branches of science. Knowledge of mires in Russia was initiated by German and Dutch experience (Peatlands of Russia ... 2001, SIRIN & MINAYEVA 2003), but later Russia contributed to the world brilliant ideas and unique experience in mire study.

The origin of mire science is rather prosaic and materialistic. In southern areas,

Photo 1: A vast expanse of Western Siberian mires. Photo by A.SIRIN.

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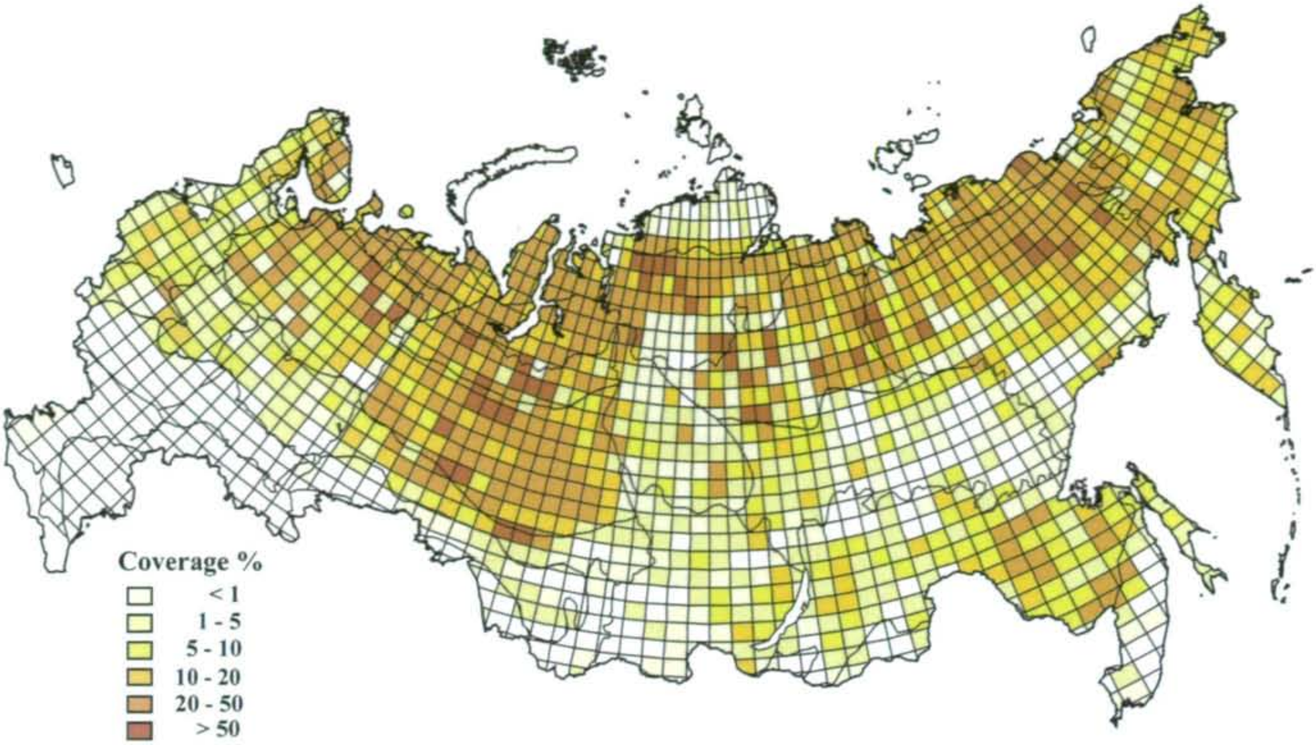

Fig. 1: Peatlands in Russia (peat depths over 30 cm), percent coverage (source: VOMPERSKY et al. 1999).

people were in need of arable lands and began to drain mires to use them for haying and pasturing. In northern areas, where there were too many mires, people drained mires to create roads and to protect pastures and arable lands from the lateral expansion of mires and from land paludification. In some regions, there was a deficit of timber for fuel and people burned peat. The aforementioned examples of direct mire use are known to have existed in Russia since the seventeenth century. In the eighteenth century, peat was already widely used both as a fertilizer and as a fuel. In the second half of the nineteenth century, mires were already considered to be a land resource, which stimulated investigations of them as objects of nature.

Two state-organized expeditions in the nineteenth century were very important for mire research and for the development of mire reclamation methods. The Western expedition, or Polesskaya, which was led by General Iosif Zhilinsky, worked in the Ukrainian and Byelarus Polessye and in central European Russia. The Northern expedition, which was led by Ivan Avgustinovich, worked in northern and north-western European Russia and in what are now the Baltic states. The aforementioned expeditions carried out large-scale investigations over the course of 20 years, beginning in 1875. Results were published in a number of editions (ZHILINSKY 1875, AVGUSTINOVITCH 1885, VIKHLYAEV 1914 etc.). The expeditions drained large territories, improved the microclimates of hard-to-reach paludified areas, and built roads. During that period, the inundation of many rivers in European Russia changed, and some experts attributed this to the reclamation work. The problem attracted public attention and launched a broad discussion on the hydrological role of mires, which eventually promoted mire research.

Research on peat and mires became a rapidly developing branch of science. Significant contributions were made by publications of famous researchers such as TANFILIEV (1888), SUKATCHEV (1914), and DOKTUROVSKI (1915). In 1914, the first issue of a new scientific journal, «Торфяное дело» (Peat Business), was published. Two peat research institutes were soon established: the Peat Research Institute (1921) and the Teaching Peat Institute (1922). During the Soviet period, peat studies were very productive. It should be noted, especially for readers outside of Russia, that VLADIMIR LENIN, who would later become the head of the first Soviet Russian government, read the book by Vladimir SUKATCHEV, "Mires:

Genesis, Development, and Features", in October 1917, and shortly after the revolution promoted and supported mire research and exploitation.

A national policy for mire research and use was created. The Russian government established the State Peat Committee as early as spring 1918; peatland inventory was launched in Russia; and field surveys of peat deposits in the central part of Russia were carried out. A special decree "On peatlands" was issued in 1922 and thus promoted the development of standardized peatlands inventory and monitoring across the country. Since 1940, the peatlands depositary has existed as an autonomous organization, and in 1980 it was integrated into the geological depositary. Presently, the peat depository is an unique database covering a great majority of peatlands. It includes mire mapping, characteristics of peat deposits, and sketches on their vegetation and hydrology. Regular inventories and publications based on standardized national surveys offered broad possibilities for peatlands studies.

Later on, the development of Russian mire science was focused on special aspects of mires' natural functions and components, from the points of view of geobotany, hydrology, landscape ecology, etc. The landscape complex approach to mire research, which is typical for the Russian school and was developed by BOGDANOVSKAYA-GUIENEUF (1969), GALKINA (1946), MASING (1974) and others, is very productive and well known among mire specialists. The Russian school of mire hydrology, which was presented by DUBACH (1936, 1944), IVANOV (1953, 1957, 1975, 1981), ROMANOV (1961, 1968a,b) and others, is considered to be the foundation of mire hydrology all over the world.

The period 1950–1970 was very productive as far as the geographical scope of studies was concerned. Numerous expeditions in mires were carried out in different regions of the country. A comprehensive description of regional mire types was given for example by PYAVCHENKO (1955, 1958) and later summarized in (1963, 1985). Beginning in 1930, mire type distribution and zonation became regular subjects of mire surveys. Well known reviews by ZINSERLING (1932) and KATZ (1948, 1971) became classical works familiar to mire scientists in Russia and abroad. Published in 1940, and later revised and republished in 1949 and 1976, a book by Sergei TYUREMNOV became a reference for many beginning and experienced mire scientists. The latest review of mire diversity in Russia that was made available to foreign readers was prepared by BOTCH & MASING (1983); this review was based on their Russian book published in 1979. YURKOVSKAYA (1992) reviewed the subject based on results of recent studies and presented it in a number of maps published in Russia and abroad.

Botanists and geobotanists in the former Mire Science Society (within the All-Union Botanical Society) contributed much to mire science. For many years (1971–1998) the head of the Mire Science Society was Marina Botch. Society activities included monthly seminars and biennial field excursions, which were associated with symposia and thematic workshops and followed by publications (Nature of mires ... 1967, Main principles ... 1972, Mire types of the USSR ... 1974, Genesis and dynamics ... 1978, Mires and mire berries 1979, Anthropogenic changes ... 1985, Methods of mire study... 1986, Peatland resources ... 1989, Structure and development ... 1989, Mires of protected areas ... 1991). The last (eleventh) field seminar-excursion was held during the waning days of the Soviet Union, in August 1991, in the Tsentralno-Lesnoi Biosphere Nature Reserve in Tver Oblast (in the European part of Russia).

Over the last decade, a number of collective studies were published. They included an analysis and clarification of peat coverage in Russia (VOMPERSKY et al. 1994, 1999), investigations of mires in several regions of the country (Mire systems of Western Siberia 2001, etc.), analyses of available information on mires (Peatlands of Russia ... 2001) and others. Collective discussions on issues such as the wise use of peatlands (Mires and paludified forests ... 1999) and the role of mires in the carbon cycle and climate change (Dynamics of mire ecosystems ... 1998, Western Siberian peatlands ... 2001) were organized. As a result of collaboration between experts in different sectors, an Action Plan for Peatland Conservation and Use in Russia (2003) was compiled and approved. Broad information exchange on problems of mire research, use, and conservation has been promoted on the website www.peatlands.ru.

Describing mires in Russia is tantamount to embracing an ocean. In this chapter, we tried to synthesize the experiences of mire experts and institutions from different regions in Russia and, through these several sketches, introduce the reader to the role of mires in nature and in the social life of this country. In the first paper, Tatiana YURKOVSKAYA presents her own view on the distribution of mire types in Russia. The authors of the second sketch offer a brief idea of main types of mire use, threats to them, and mire conservation in Russia. Two additional regional papers are devoted to two contrasting mire sites – one in Western Siberia, and one in Western European Russia. A group of authors prepared a paper describing the world's largest mire – the Great Vasyugan Mire. We are sorry to say that this was the last work of Olga LISS, a mire scientist who devoted many years of her life to the selfless study of Western Siberia's expansive mires. The chapter ends with a short sketch about inner-mire mineral islands in the Polisto-Lovat mire system in western European Russia and about the interactions of mires with other landscapes and man. We hope that readers will acquire some sense for Russian mires, for their diversity, and for their importance to humans.

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Distribution of Mire Types in Russia

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Abstract: Mire distribution is distinctly connected with bioclimatic zonation. From tundra regions, to the southern limit of the taiga, the following mires types give way to each other sequentially: polygonal, palsa, ribbed fens (aapa), and raised bogs. Herbaceous and herbaceous-moss fens occur in all zones and regions. From the north to the south, they differ in their community structure, species composition, and syntaxonomical composition. In boreal and nemoral regions, forest swamps are distributed. In each bioclimatic zone, not one, but rather several, of the aforementioned regional mire types is found, and their distribution ranges are overlapping.

Key words: bioclimatic zonation, polygonal mire, palsa mire, ribbed fen, bog, unpatterned fen, swamp, Russia

Introduction

With its borders extending for 60.900 km, Russia occupies a considerable part of northern Eurasia. The country's territory stretches for more than 4.000 km from north to south, and for 10.000 km from west to east. When considering the geography of vegetation cover (including mires as an integral part), it is worthwhile to examine a geographical map. It helps to have an understanding of the actual size of the country, its reach from north to south, and from west to east, and to realize its place among other countries and its position on our planet. A geographical map offers the opportunity to see the location of low and up-lifted plains, mountains, rivers, lakes, and seas, i.e. the whole environment in which living nature exists. Therefore, I recommend that you have a geographical map in front of you when reading this paper.

First, of all, look at a map of Eurasia, and then at a map of Russia. You'll see that Russia's westernmost point is located on the Baltic Spit (19°38´ E). The easternmost point on the continent is on the Bering Strait, which separates Asia and North America; specifically, this point is Point Dezhnev, located on the Chukotka Peninsula (169°40´ W). The easternmost point on an island can be found on the eastern shore of Ratmanov Island (169°02´ W). Russia's northernmost point on the continent is situated in Siberia, on the Taimyr Peninsula, at Point Cheluskin (77°43´N), whereas the northernmost point on an island is Point Fligeli on Rudolf Island (81°51´N), which is part of the Franz Josef Archipelago. And, finally Russia's southernmost point can be found in the Caucasus, on the border with Azerbaijan and southwest Mount Bazardzuzu (41°00´ N).

The main factor influencing mire type distribution is climate. Thus, we will introduce Eurasian bioclimatic zonation and how it presents within Russia. We will further follow these zones to describe mire types.

Bioclimatic Zonation and Azonal Factors

Two huge lowlands lie in the western part of Russia: the Eastern European Lowland in European Russia and the Western Siberian Lowland in the Asian part of the country. They are separated by the Ural Mountains. In these plains, bioclimatic zonation is clearly pronounced. At the same time, almost the entire eastern part of Asian Russia (from the Yenisey River eastward) is occupied by mountains and high plateau. It is well known that, in mountainous areas, it is difficult to trace latitudinal zonation as al-

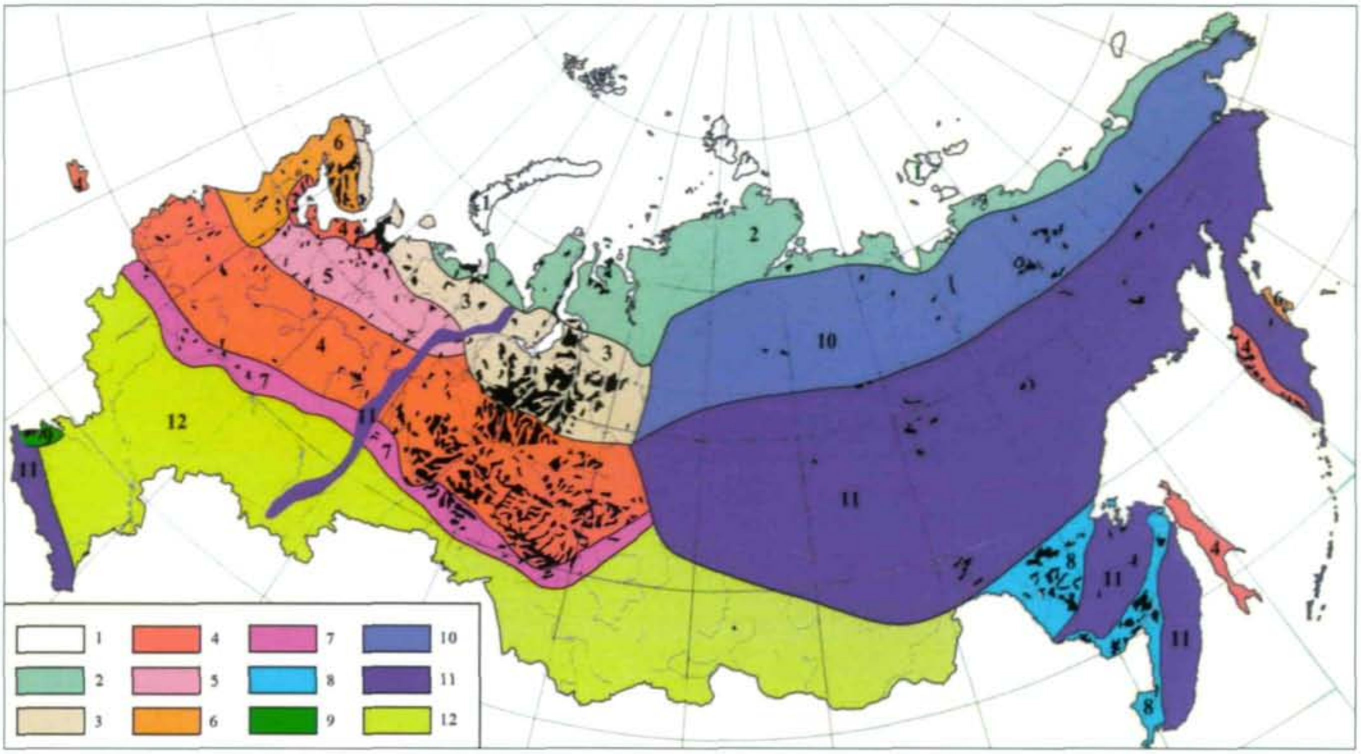


Fig. 2: Mire Distribution in Russia. 1 – Herbaceous-moss fens; 2 – Polygonal mires and herbaceous-moss fens; 3 – Palsa mires with participation of ribbed fens and unpatterned fens; 4 – Raised bogs; 5 – Raised bogs with participation of ribbed fens; 6 – Raised bogs with prevailing ribbed fens; 7 – Raised bogs with prevailing fens; 8 – Herbaceous-sedge fens with raised bogs and occasional palsa; 9 – Reed fens; 10 – Mires in mountains, muskeg, and palsa; 11 – Mires in highlands; 12 – Territory with occasional presence of mires.

titudinal zonation becomes more pronounced. Zonation is also affected by the huge expanses of ocean area that are responsible for transferring air masses and thus, moisture. First, in the Far East, let us note the influence of Pacific monsoons, which transform zonal regularities and influence all natural processes in the region. In the North, the Arctic Ocean's cold masses play a great role, as 14% of Russia's territory is situated north of the Polar Circle. In the West, Atlantic Ocean air masses penetrate the continent as far as the Western Siberian Lowland. Therefore, there is not a single bioclimatic zone, which extends across the country from west to east, as might be seen on some maps. Latitudinal zonation is well-defined within certain meridial sectors and provinces, primarily within the plains. Five bioclimatic zones are distinguished within Russia. They are, from north to south: Arctic (tundra); boreal (taiga); nemoral (broad-leaved forest); steppe; and desert. Only in the European part of Russia can one observe all of the aforementioned zones in their typical sequence. In Siberia, the nemoral zone is absent, although it appears again in the Far East. In Asian Russia, the steppe zone is represented only by its northern subzones. In Asia, both the southern part of the steppe zone and the desert zone can be found only outside of Russia. Mire distribution is distinctly connected with bioclimatic zones and subzones. The highest percentage of mires by area can be observed in the northern part of the country. In some boreal regions, such as the Western Siberia or White Sea Lowlands, for example, the portion of paludified lands can be as high as 50-80%.

Latitudinal Mire Distribution (Mires from North to South)

After briefly introducing you to Russia's bioclimatic zonation, we will now lead you through the entire country from the far extreme north to the south. From the tundra to the southern limit of the taiga, the following types of mires give way to each other sequentially: polygonal, palsa, ribbed fens (aapa), and raised bogs (Fig. 2). Herbaceous and herbaceous-moss fens have the widest distribution range. They are found from the high arctic till the southern limits of Russia. It does not however mean that those mires are azonal. From the north to the south they change their floristic composition, syntaxonomy, and type along with the latitudinal gradient.)

Arctic Mires

The Arctic is considered to be the territory situated north of the polar forest boundary up to the northernmost terrestrial limits (ALEXANDROVA 1980). Within Russia, the Arctic occupies a vast area extending longitudinally over 150°, from the Atlantic to the Pacific Oceans. Mires comprise a significant part of vegetation cover in the Arctic, except in high latitudes (the High Arctic Tundra Subzone). The main reason for this is that permafrost creates a layer that is impenetrable by water. During the short period of warmth in the summer, water from snow melt stays in place because of "hydroisolation". Permafrost is also responsible for the uniquely patterned structure of Arctic mires, which is formed by thermokarst processes.

The Arctic mire systems are presented by **herbaceous** and **herbaceous-moss fens** in river and stream valleys and in sea lowlands, and **polygonal mires** and **palsa mires** in watersheds.

Polygonal mires are the most remarkable Arctic mire type. My colleague, Prof. Galina ELINA (1993), has come up with an apt expression for them: "checkered mires." Their polygonal structure arises from the network of deep cracks, which divides the mire surface into polygons.

Scientists have distinguished low-centred and high-centred morphological types in polygon mires. High-centred complexes are comprised of flat polygons separated by cracks, as can be seen in the picture. Thus, high-centred polygon mire complexes have two morphological elements: polygons and cracks. Low-centred complexes have plate-like depressions in the center of the polygon, which form a hollow. The lower part of the polygon, or hollow, is distinguished from the crack by a type of rim. Therefore, three morphological parts can be distinguished in low-centred polygon mires: a hollow, a rim, and a crack. The hollow and rim form a polygon. The scheme (Fig. 3) helps to understand the entire structure.

The height of the polygons varies from 0.25 to 0.7 m, and their diameter ranges from 10 to 40 m. Rims rise above the hollows by 0.25–0.35 m and have widths ranging from 1 to 4 meters. Crack widths are described as being 0.5–1 m for the European North, while PYAVCHENKO (1955) has reported widths of 4 m and more for the Yamal Peninsula.

Peat deposits in polygon mires are formed by sedges, brown mosses and horsetails. They are shallow and often include silt or sand. For most of the year, the peat is frozen, which prevents it from decomposing.

Typical vegetation cover structure, including that for polygonal mires, is presented by mixed mire massifs formed by combinations of polygonal complexes and homo-

Photo 2: High-centred polygon mire complexes in Eastern European northern tundra.

Fig. 3: The entire structure of polygon mires. 1 – polygons and cracks; 2 – hollows in polygons; 3 – sedge-cotton grass fens

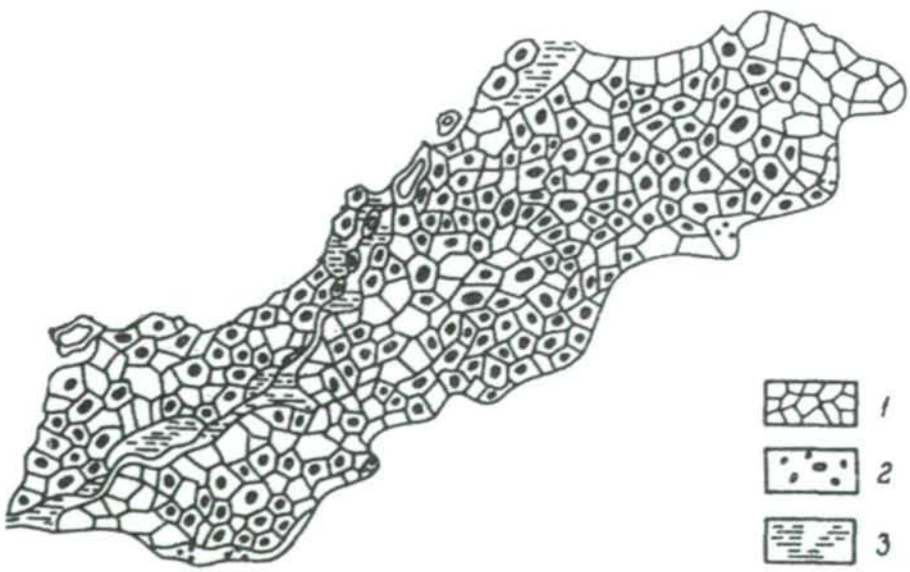
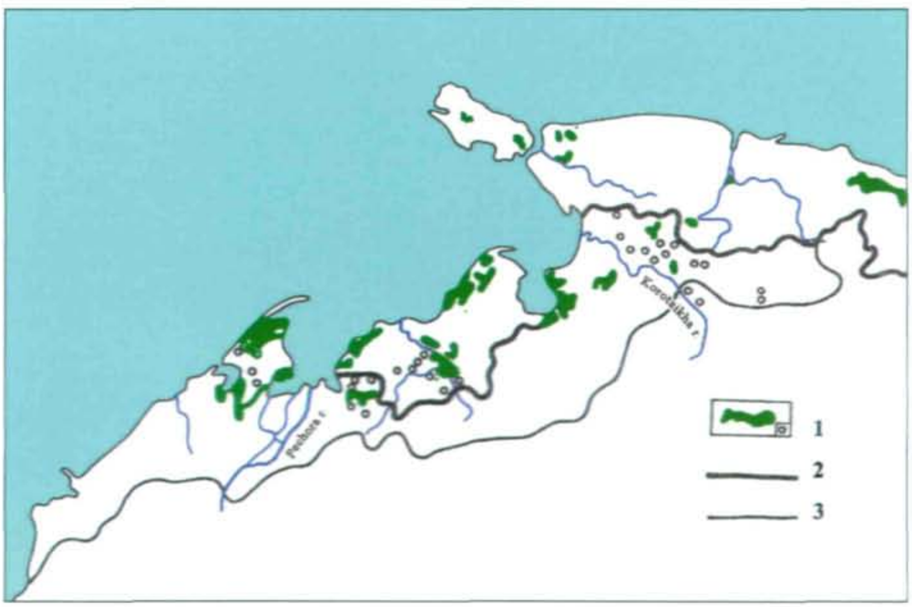


Photo 3: Low-centred polygon mire complexes in Taymyr peninsula. Photo by A.NECHAEV.

geneous sedge fens. Fig. 3 presents a large-scale map, which illustrates such a mire massif. It includes a linear depression with a stream, surrounded by sedge and sedge-cotton grass plant communities, together with polygonal complexes of different forms such as quadrangular to polygonal, with a flat surface or various-sized hollows bordered by rims.

For a long time, polygonal mires were considered to be a typical phenomenon for Asian Russia and the North American Arctic only (KATS 1948, BOTCH & MASING 1979, KIVINEN & PAKARINEN 1981, etc.). To some extent, this is true; they are more widely distributed in the continental climatic conditions of the Asian part of Russia. Polygonal mires are widespread on the Yamal Peninsula, and frequently occur on the Gydan and Taymyr Peninsulas, and in Northern Yakutia and Chukotka (Fig. 2). However, in a map published in 1979, I presented data on polygonal mire findings in the northeastern part of European Russia (ISACHENKO & LAVRENKO 1979). Through aerial-visual and land-surface field studies, together with aerial photographs analysis, S.A.GRIBOVA and I discovered a rather extensive range of polygonal mires located beyond their previously known geographic limits (GRIBOVA & YURKOVSKAYA 1984). This altered the traditional understanding that polygonal mires are a typical feature for the northern part of Asian Russia and for North America. In European Russia, polygonal mires are confined to the northern (typical) tundra strip and occur in its northeastern part (Fig. 4) in the Malozemelskaya and Bolshezemelskaya tundra and on the Yugor Peninsula. They are found in the basins of the Kheyakha, Sibirchatayakha, Korotaykha and Chernaya Rivers, extending to the Kara River. The westernmost locations of polygonal mires were recorded in the eastern part of the Malozemelskaya tundra, in the region of the Nenetsky Ridge. Here, they are especially numerous in the Neruta River Valley. The southernmost polygonal mires are recorded in the upper flow of the Kolva River. These results have been reflected in a number of maps, including "Vegetation Map of Europe" (2001), as well as in other publications (YURKOVSKAYA 1992, SUCCOW & JOOSTEN 2001). I have shown polygonal mires for the entire Russian Arctic in the "Vegetation Map of the USSR" (1990).

Fig. 4: Distribution of Polygonal Mires in the European Part of Russia: 1 – Polygonal mires; 2 – Southern boundary of the northern tundra; 3 – Boundary between low-dwarf-birch and tall-dwarf-birch strips of the southern tundra.



The southern limit of polygonal mires generally coincides with the southern boundary of the northern (typical) tundra subzone, although in some places the mires extend southward and occur in a northern strip of the southern tundra subzone, a strip of low-dwarf-birch tundra (Fig. 4). The southern boundary of polygonal mires in the European North is shifted considerably northward, compared to that in western Siberia. In general, the latitudinal range of polygonal mires in northeastern Europe is substantially narrower than it is in Siberia.

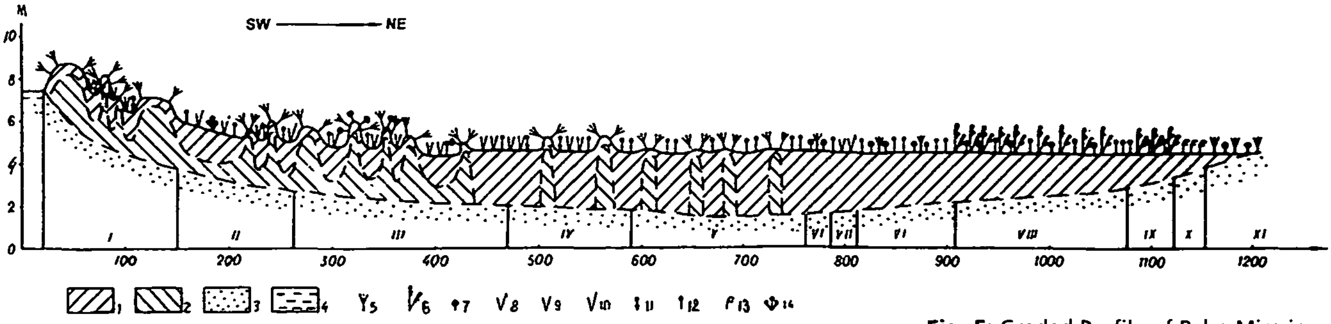


Fig. 5: Graded Profile of Palsa Mire in Northern Forest-tundra (Pechora River Basin). I – Palsa weakly divided complex; II-III – Palsa-ridge-hollow complexes; IV-VI – Flat palsa complex; VII – Herb swamp; VIII – Edge vegetation. 1 – Melted peat, 2 – Frozen peat, 3 – Mineral ground, 4 – Water, 5 – *Ledum palustre*, 6 – *Chamaedaphne calyculata*, 7 – *Rubus chamaemorus*, 8 – *Carex magellanica*, 9 – *C.rariflora*, 10 – *C.rotundata*, 11 – *Eriophorum vaginatum*, 12 – *E.russeolum*, 13 – *E.polystachion*, 14 – *Baeothryon caespitosum*.
Note: The bottom is represented by a dotted line. Therefore, the sampling of mineral ground was conducted for melted peat only; for frozen peat, it is estimated.

REBRISTAYA (2000) wrote that on the Yamal Peninsula, polygonal mires extend from the southern strip of the Arctic tundra subzone up to the northern forest-tundra, but they are most numerous and floristically rich in the subzone of northern (typical) tundra.

Herbaceous and herbaceous-moss fens are distributed across the entire Arctic. In the high Arctic, on the islands of the Arctic Ocean (Franz Josef Land, Novaya Zemlya, Severnaya Zemlya, and the DeLong Islands) only herbaceous-moss fens occur. Most typical for the coastal part of the Arctic are grass-sedge fens with *Dupontia fischeri* and *Carex stans*. These fens are characterised by high water saturation and often merge with salted marshes, thus forming huge wetlands. Throughout the entire tundra, except in the high Arctic, sedge-cotton-grass-moss fens occur with *Eriophorum medium*, *E. russeolum*, *E. polystachion*, *Carex chordorrhiza*, *C. concolor*, *etc.* in river and stream valleys, in lake depressions, as well as in coastal lowlands (at some distance from coast). In Siberia, peculiar fens called "*khasyrei*" can be found. They replace lakes naturally drained due to the thermokarst processes, what is usual phenomenon in this area. These fens are overgrown with long rhizomatous grasses and cotton grasses (*Arctophila fulva*, *Calamagrostis langsdorfii*, *Dupontia fisheri*, *Eriophorum scheuchzeri*).

In his review, KATS (1948, 1971) recognized the integrated zone of sedge mineral fens without delineating a special zone for polygonal mires. Regardless, I managed to find descriptions of this key fen type only in publications after REBRISTAYA (1977, 2000).

Another peculiar mire type is the so-called "**palsa-mire**" type. It is associated with the sporadic distribution of permafrost. "Palsa" is a term to describe a mound of peat containing a core of ice lenses that remain frozen throughout the year. Palsa have various forms. They may be rounded, laciniate, or stretched into ridge-like forms. The top of palsa can be dome-shaped or flat. Palsa varies greatly in size. Their height averages from one to four meters, with diameters ranging from 10–30 m. Much larger palsas have also been described. Palsa differ not only in their morphology, but also in their location within the structure of mire massifs. They may be presented by a single palsa with an adjacent hollow or lake; or by a group of palsas in the middle of water. Some mire massifs with palsas can be likened to raised bogs in their morphology and complicated structure of vegetation cover. The highest part of such a mire massif usually has a palsa complex, which is hardly pronounced. The slopes are occupied by high palsa-hollow and high palsa-ridge-hollow complexes. At the edges, flat palsa-hollow complexes follow each other, and after them, marginal herbaceous-swamps extend up to the edge of the mire. Sections of such massifs have a complicated, graded profile (Fig. 5).

Peat deposits in palsa mires are diverse in composition. Peat depth can reach 4.5 m, but is usually much less deep. Deposits are primarily frozen and can melt in the summertime up to depths of 25–40 cm below the surface of the palsas, and from 75 cm and more to the bottom in hollows.

For palsa, species of dwarf birch are most characteristic, and are especially abundant at the foot of palsas. Regional differences are marked by different dwarf birch species. For example, *Betula nana* grows in the European North and in western Siberia, whereas *B. exilis* can be found in central and eastern

Photo 4: On a flat palsa mire. The author and Prof. Stanislav Vompersky are standing at the center of the group.
Photo by A. SIRIN.

Siberia. European palsas are usually treeless. In western Siberia, *Pinus sylvestris*, *P. sibirica* and sometimes *Larix sibirica* grow on palsas, while in eastern Siberia and in the Far East – *Larix gmelinii* grows. Among local features, one can note the absence of *Ledum* species on palsas on Kolguev Island, while it regularly occurs on palsas on the continent. The tops of high palsas are often eroded and lack vegetation. Lichens are sometimes abundant on palsas, especially *Cetraria cucullata* and *C. nivalis*.

In European Russia, palsa mires appear south of the Arctic, but they are most distinctive outside of it, in the forest- tundra subzone. In Asian Russia, the geographic range of palsa mires lies outside of the Arctic, extending from the southern forest-tundra to the northern taiga, inclusively, and moving far southward over the mountains and occurring locally in regions with permafrost islands, for instance, almost in the southern Far East. Their northernmost location is on Kolguev Island. Russia's palsa mires are described by PYAVCHENKO (1955). Their geographic range may be termed Arctic-boreal, and if one uses floristic terminology, they have typical meta-arctic range. It should also mentioned that the region of palsa mire distribution is the ecotone between the Arctic and boreal mire ranges. It should be noted that Arctic mires are poorly studied, and that most investigations were conducted before the 1950s. Mire scientists work in the Arctic on a case to case basis. The exception to this is the study by PYAVCHENKO (1955). Arctic mires are also underrepresented in official state inventories, such as geological surveys. They are, however, partly mapped within the land cadastre.

Photo 5: Closer to river valleys the palsas become of considerable height.
Photo by A. SIRIN.

Boreal Mires

Boreal mires are presented by ribbed fens (or "aapa" mires) and raised bogs.

The next mire type in the north-south sequence is **ribbed fen (aapa mires)**. Since CAJANDER (1913) described and defined this mire type for the first time, ribbed fens have attracted the attention of researchers (ZINSERLING 1932, 1938, KATS 1948, YURKOVSKAYA 1964, 1992, ELINA et al. 1984, KUZNETSOV 1986, ALEKSEEVA 1988, etc.). Nevertheless, our knowledge of these mires has been poor up until now. The main features of ribbed fens are as follows: they have a concave surface; high water saturation in the central part with a heterotrophic string-flark complex; and an oligotrophic development trend at the periphery. The latter means that the center of the mire is occupied by communities with higher mineral nutrition demands. Usually, these are herbaceous and herbaceous-moss communities in flarks, and herbaceous-sphagnum on strings, while at the edges, they are mesooligotrophic dwarf shrub-peatmoss with pine trees and *Sphagnum fuscum*.

Atmospheric, deluvial water, and underground water discharge provide water-mineral supply. The diversity and relative richness of mineral nutrition are responsible for the diversity of vegetation cover in ribbed fens. There, we find three dominating synusia: herbaceous, peatmoss and brown moss (*Amblystegiaceae*). Their ratio and role in the composition of vegetation cover varies distinctly depending on their location within the mire massif. The positive elements of microrelief and marginal parts of mire massifs are dominated by peatmoss synusia. Negative forms of microrelief, mainly in the central parts of the mire massifs, are occupied by herbaceous and brown mosses synusia. The presence of herbaceous flarks, which lack moss cover, is one of the characteristic features of ribbed fens. The increasing role of sphagnum synusia in the north and south of the geographic range of ribbed fens massifs should be noted. They are well distinguished by airplane, as well as in aerial and satellite images, due to the peculiar structure of string-flark complexes: thin, winding light strings on a dark background of watered flarks.

The heterogeneity of vegetation cover is reflected in peat deposit composition (Fig. 6). Peat deposits are eutrophic or mesotrophic in the center, and mixed at the edges of the mire massif. The picture illustrates the differences in botanical composition and pH indices under different elements of a string-flark complex (high string with *Sphagnum fuscum*, low string with the dominance of *S. papillosum* and flark). As a whole, the peat deposit is comprised of eutrophic and mesotrophic peat, with thickness varying from 1–2 to 6–7 m.

Photo 6: Ribbed fen in the north taiga in West Siberia. Photo by A. SIRIN.

Photo 7: Ribbed fen from the air. Photo by P. TOKAREV.

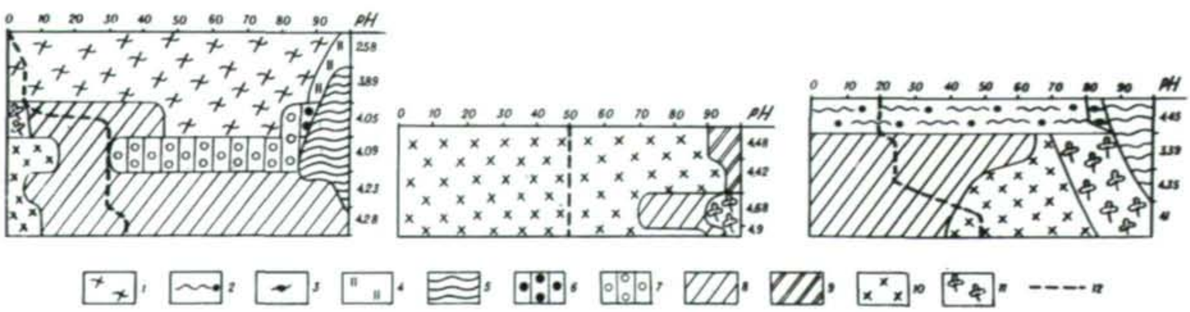


Fig. 6: Heterogeneity of a String-flark Complex of Ribbed Fen. 1 – *Sphagnum fuscum*, 2 – *S. papillosum*, 3 – *S. warnstorfii*, 4 – *Dicranum sp.*, 5 – cotton grass, 6 – pine, 7 – birch, 8 – sedges, 9 – macrofossils of herbs, 10 – *Equisetum*, 11 – *Menyanthes*, 12 – degree of decomposition (%). Figures above – percents, right column are indices of pH_{KCl} in corresponding horizons of peat, left scale is depth of peat deposit (cm).

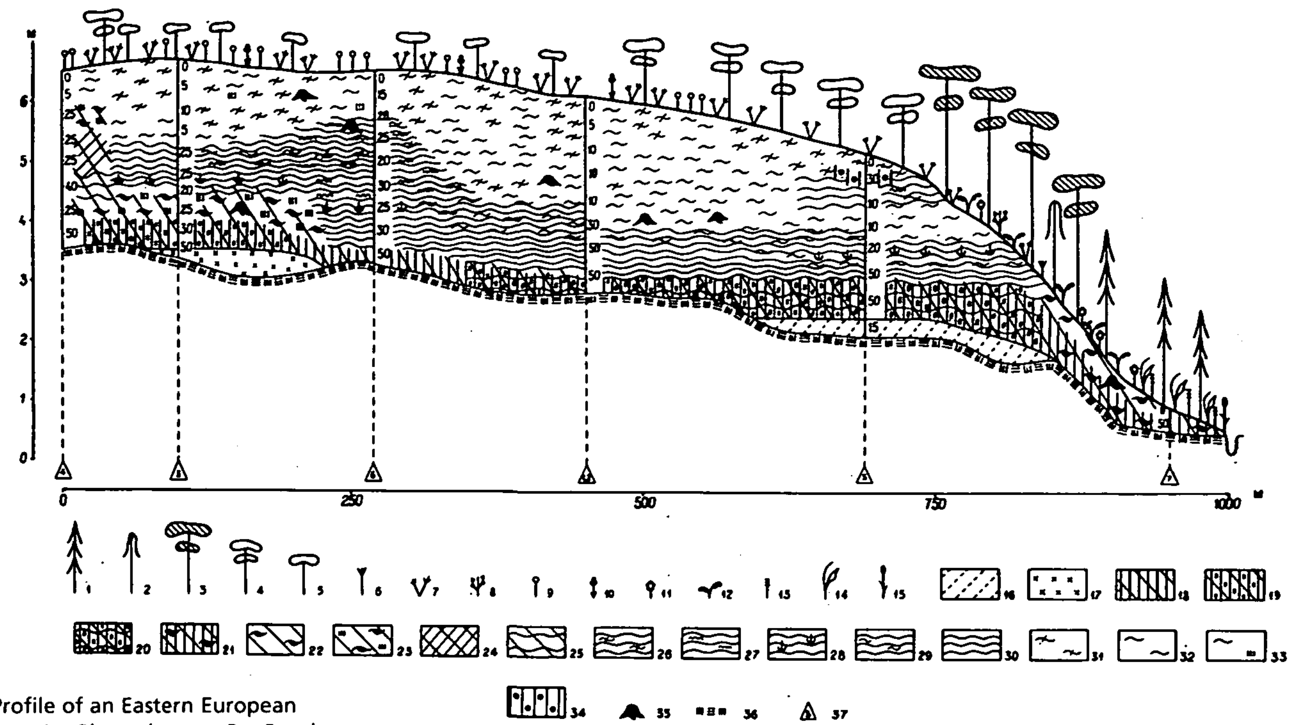


Fig. 7: Profile of an Eastern European Raised Bog. 1 – *Picea obovata*, 2 – *Betula pubescens* 3 – *Pinus sylvestris* f. *uliginosa*, 4 – *P. silvestris* f. *litwinowii*, 5 – *P. sylvestris* f. *wilkommii*, 6 – *Ledum palustre*, 7 – *Chamaedaphne calyculata*, 8 – *Betula nana*, 9 – *Eriophorum vaginatum*, 10 – *Scheuchzeria palustris*, 11 – *Rubus chamaemorus*, 12 – *Vaccinium myrtillus*, 13 – *Equisetum fluviatile*, 14 – *Calamagrostis canescens*, 15 – *Phalaroides arundinacea*; eutrophic peats: 16 – Hypnum, 17 – Equisetum peat; transitional peats: 18 – wood, 19 – birch, 20 – birch-cottongrass, 21 – wood-Sphagnum, 22 – Sphagnum, 23 – Scheuchzeria-Sphagnum, 24 – sedge, 25 – cottongrass; raised-bog peats: 26 – cottongrass-Sphagnum (*Sph. fuscum*), 27 – cottongrass-Sphagnum (*Sph. magellanicum*), 28 – cottongrass-Sphagnum (*Sph. angustifolium*), 29 – cotton grass-Sphagnum (Sph. hollow), 30 – cotton grass, 31 – fuscum, 32 – Sphagnum hollow, 33 – Scheuchzeria Sphagnum hollow, 34 – pine, 35 – stump, 36 – clay, 37 – pit number.

Investigations conducted during the last quarter of the twentieth century confirmed the *a priori* statement of RUUHIJÄRVI (1960) about the panboreal distribution of ribbed fens. Localities of ribbed fens in Canada have been mapped (ZOLTAI & POLLETT 1983, WELLS & ZOLTAI 1985). They occur in the northern USA from the state of Maine over to Minnesota (GLASER et al. 1981, HOFSTETTER 1985, DAVIS & ANDERSON 2001). Some data on ribbed fens in Siberia are also available (STOROZHEVA 1960, ROMANOVA & USOVA 1969, TODOSIJCHUK 1974, PREYS 1978, SMAGIN 2002). Analysis and interpretation of satellite images has definitively confirmed the pan-boreal distribution of this mire type. The geographical distribution of ribbed fens differs in the European and Asian parts of Russia. In European Russia, they are restricted to forest-tundra, northern, and middle taiga. In Asian Russia, their range is wider, and they extend from the southern tundra to the southern taiga. Thus, the northern part of their range overlaps with that of palsa mires, whereas in the southern part of their range, they overlap with raised bogs (Fig. 2). The nature of Asian ribbed fens has been studied very little. Nevertheless, it is known that ribbed fens always occur together with mires of other types (palsa and raised bogs). In only a few regions, does the area occupied by different mire types change depending on geomorphologic, edaphic, and hydrologic conditions, just following the regularity of changes in dark and light coniferous forests in the taiga.

Raised bogs are the most dominant mire type in Russia, both in their coverage and in peat storage. They are most diverse with respect to their complicated structure, genesis, and geomorphology. Common features for raised bogs are: a domed surface; poor, but highly specific biota; thick peat deposits formed by sphagnum oligotrophic macrofossils; primarily atmospheric nutrition; and low levels of mineralization and high acidity of water and peat.

Large bogs have lake genesis, and their size increases at the mire's expense to the surrounding territory. According to phytosociological literature, raised bogs primarily include communities of the *Oxycocco-Sphagnetea* class, but in this paper, raised bogs are considered as massifs on the whole, correspondingly including all diversity of macro- and meso-forms and corresponding vegetation from the top of the bog down to the border of mineral soil. Therefore, if the essential floristic composition of raised bogs numbers 20 species of vascular plants, it totals 60–90 species for the whole massif. In their form, raised bog massifs resemble miniature hills. They have a mire massif's distinct top, slope, and foot (edge) (Fig. 7). According to macroform classification, distinctly convex, gradually-convex, and flat-convex peat bogs are distinguished (GALKINA 1946). Only a few raised bogs in Russia have a classic concentric form; the majority of them have a gradually-convex surface (excentric bogs).

Raised bogs are concentrated in the taiga, but extend beyond it southward, to the nemoral region up to forest-steppe. According to BOGDANOVSKAYA-GUIENEUF (1949), we differentiate three groups of raised bogs: "Fuscum", "Magellanicum" and "Degraded". These three categories reflect regional differentiation and the dynamic status of raised bogs. The group "Fuscum" covers typical boreal raised bogs, in which sphagnum mosses have the most significant community-building role. The "Magellanicum" type consolidates all typical raised bogs of the southern taiga, the hemiboreal and nemoral zones, where peatmosses are somewhat overcome by well developed tree stands. In the "Degraded bogs" group, we find raised bogs where the role of peatmosses is weakened by the processes of erosion and denudation that are associated with periodic floods and frost. Peatmosses here are replaced by liverworts and lichens.

In their dynamic aspect, bogs of the "Fuscum" group correspond with the mature phase of raised bogs, in conditions of optimal development. Bogs of the "Magellanicum" group correspond with the mature phase, in conditions of limited development. Bogs of the "Degraded bogs" group correspond with the concluding phase, in conditions of regressed peat formation. Raised bogs of the "Fuscum" group are the most widespread in Russia. Elsewhere in Eurasia, their distribution is limited mainly to northwestern Europe. "Magellanicum" bogs in Russia represent the eastern (continental) part of this group's geographic range, which is now essentially absent from Europe due to peat extraction and drainage. "Degraded" bogs are located primarily in the sub-oceanic boreal and hemiboreal regions, and also include large massifs in moderately continental taiga regions on the Eastern European and Western Siberian plains.

Photo 8: A hollow with bare peat in the northern taiga of the European part of Russia. Photo by author.

Russian mire science does not traditionally give geographical names to regional types of mire massifs. Thus, their distributional range is underscored. The Fuscum group contains 7 regional types of bogs: North-Karelian, Mid-Karelian, Northwest-European, East-European, West-Siberian boreal, West-Siberian Sub-boreal, and Far-Eastern. Degraded bogs types are equally diverse: West-Baltic, East-Baltic, White Sea Coastal, Northeast-European, North-Mid-Ob, Sakhalin, and West-Kamchatka. The raised bogs of the Magellanicum group are represented in Russia by two types: Mid-Russian and South-Russian. A truly tremen-

Photo 9: A ridge-pool complex in the raised bog. Photo by author.

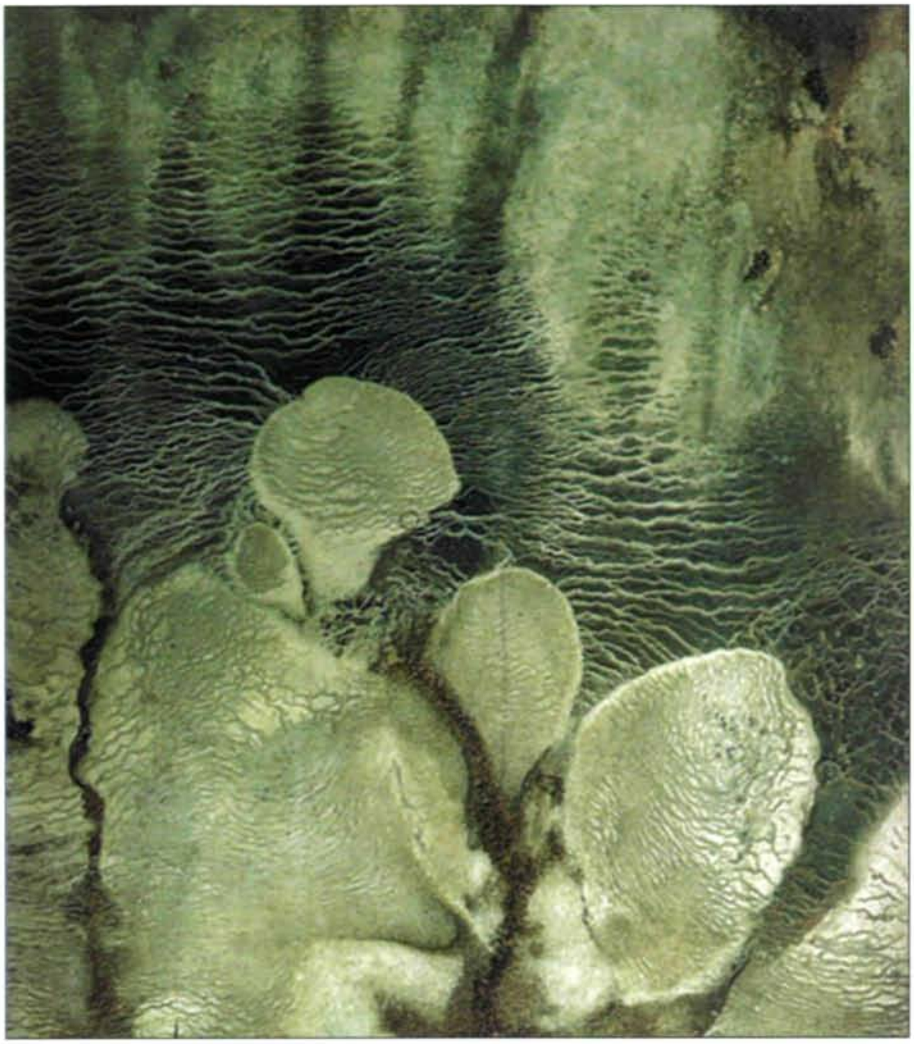


Photo 10: An aerial view of a mire system formed by raised bogs and ribbed fens. Sebboloto, Archangelsk oblast, Northern taiga.

dous bibliography, which ranges from classic works to modern publications, is devoted to Russia's raised bogs. It is impossible to describe them all in a brief outline.

The most characteristic structural parts of raised bogs are the ridge-hollow and ridge-pool complexes. Depending on the type of bog, they are located on tops or slopes. The pattern of these complexes is well pronounced in aerial or satellite images.

Ridge-pool and regressive complexes are especially typical for degraded raised bogs. In regressive complexes, hollows lack peat-moss cover and bare peat is exposed on the surface. On ridges, *Sphagnum fuscum* disappears almost completely, as well, and it is replaced by lichens.

Ridge-hollow complex diversity depends on the differences in size and ratio of ridges and hollows. In small hollows, *Eriophorum vaginatum* dominates, in larger and watered ones, *Scheuchzeria palustris, Carex limosa* and other hydrophyllous species. Only a few types of raised bogs have homogeneous vegetation cover; these are usually small, pine-dwarf shrub-sphagnum bogs. They can be found throughout the entire range of raised bogs types, but especially near their southern limit. In European Russia, they are represented by the South-Russian type of the Magellanicum group, and in Siberia, by the West-Siberian Sub-boreal type, known by the term "*ryam*". This is a rather peculiar type, with a distinctly concentric structure. The typical appearance of these mires is: not large, sharp convex bogs with pine, dwarf-shrubs and *Sphagnum fuscum*, rarely of *S. magellanicum*. They are confined to the southern limits of the taiga, particularly to its small-leaved birch-aspen subzone. Some authors delineate this strip as being a separate bioclimatic zone. These raised bogs of the "*ryam*" type are also found in the forest-steppe subzone. It is typical for these mires to have a lag as a strip of highly water-saturated tall-grass fens with *Phragmites australis, Scolochloa festucacea*, and tall sedges. It is presumed that this strip of fens is a buffer against the penetration of salts into the waters supplying the "*ryam*," as soils of this strip, especially in the forest-steppe, are very salty.

Changes in the vegetation of raised bogs from west to east are consistent with those in zonal vegetation, but they are less pronounced and much more weakly expressed than changes in mire vegetation in the latitudinal direction. So, throughout the Mid-taiga area, the main forest dominants replace one another from west to east. But, in raised bogs across the entire Mid-taiga, *Sphagnum fuscum* predominates. Only the presence of geographically different species causes some changes at the level of associations and sub-associations. More seldom, higher syntaxa allows one to distinguish regional types among raised bogs. For instance, in the Fuscum group, the North-West-European type is characterized by *Calluna vulgaris, Chamaedaphne calyculata, Sphagnum rubellum*; in the North-East-European type, *Calluna vulgaris* and *S. rubellum* disappear, but *Chamaedaphne* still dominates in West-Siberian bogs throughout the entire range, as does *Pinus sylvestris*, *P. sibirica*, while ridge vegetation is presented by *Empetrum subholarcticum* and abundant *Vaccinium vitis-idaea*.

In the group of degraded raised bogs, changes in species and syntaxa composition are not very considerable and are gradual. In the East-Baltic and White Sea Coastal bogs, *Calluna vulgaris* dominates on ridges; lichens are also abundant. At the same time, species composition reflects the more western and southern position of the East Baltic (*Sphagnum rubellum*, *S. magellanicum*, *S. cuspidatum)* and the more northern position of the White Sea: (presence of *Sphagnum lindbergii*, absence of *Sphagnum cuspidatum*, *S. rubellum*, abundance in hollows of *Carex rariflora*, instead of *Carex limosa*, presence of *Cetraria nivalis*). On Sakhalin Island, *Sphagnum lenense* is the distinguishing species in bogs of this group; on Kamchatka, *Carex middendorfii* is the distinguishing species.

Sphagnum transitional mires have a special place among other mire types. On the vegetation map of the USSR, I recognized five regional mire types, ranging from the western boundary of Russia to the Pacific Ocean (Vegetation of ...1990). It is very important, that this sphagnum bog type be traced far northward (to the northern forest-tundra) and far southward (to the steppe). By this way, that offers the chance for numerous boreal species to advance further to the north and south within that mire type.

Boreal and Nemoral Unpatterned Fens and Swamps

Herbaceous and herbaceous-moss fens have their own special place in mire vegetation. They are found within all zones and regions. We have already noted their characteristic features in the Arctic. In the boreal zone, both small-sedge and tall-sedge fens with *Carex nigra*, *C.lasiocarpa*, *C. rostrata*, *C, vesicaria*, *etc.* are described. In the nemoral area, tall-sedge fens with *Carex acutiformis*, *C.riparia*, *C. omskiana* prevail. The tall-grass-reed, reed-sedge fens are typical for the steppe zone. In the Far East, there are very typical fens dominated by *Calamagrostis langsdorfii*, *Carex middendorfii*. Various types of fens differ not only by species and syntaxonomical composition. From north to south, they are distinctly differentiated by community structure. For example, an analysis of changes in the mean layer of herbaceous plant height within communities of unpatterned fens from north to south in Eastern Europe creates a very distinct picture (YURKOVSKAYA 1992).

Photo 11: *A sedge fen in the Ob River valley in Western Siberia. Photo by A. SIRIN.*

Forest swamps are also typical for the boreal and nemoral region. In the northern boreal region in the European part of Russia, these are predominantly birch; spruce-birch swamps are especially widespread in the territory leading up to the Ural Mountains. Starting from the southern taiga and in the nemoral region, including forest-steppe, alder-swamps (with *Alnus glutinosa*) are widely distributed in the European Russia. In Siberia, *Alnus glutinosa* dose not occur, but forest-swamps are very characteristic for southern Siberia (LAPSHINA 2003). In Siberia, they are called by a local term, "*sogra*", and are characterized by well developed mixed tree-stands of *Betula pubescens*, *Pinus sibirica*, etc. The so-called peatmoss muskegs, with a layer of dwarf-birch, often with larch (*Larix gmelinii*, *L. cajanderi*), comprise a type quite characteristic for East Siberia and the Far East.

Photo 12: A black alder-spruce swamp in the southern taiga of the European part of Russia. Photo by A. SIRIN.

Conclusion

Thus, one can observe a distinct picture of successive latitudinal changes in mire types from north to south. These changes correlate with bioclimatic zones. From the north to the south, not only the flora and vegetation of mires changes, but also their morphology, peat deposit, and hydrological regime. Large groups of mire massifs, uniting, in their turn, regional types, also change from north to south. Regional types form within groups due to changes along the oceaneity-continentality gradient in a west-east direction, or, more precisely, in two directions – from the west (sub-Atlantic) and from the east (Pacific) to the ultra-continental eastern Siberia. These changes definitively form regional types, but are chiefly reflected in floral composition and in changes in low-level syntaxonomical units (associations and subassociations). One of the essential conclusions of the conducted analysis is that no zone is dominated by a single mire type or group of types, as supporters of mire zone demarcation believe (KATS 1948, BOTCH & MASING 1979 etc.). Each bioclimatic zone or subzone (strip) is characterized not by one regional type, but by several. In other words, within an individual bioclimatic zone, the ranges of several types of mires overlap. It should also be mentioned that analysis of mire distribution should be based on cartographic sources, as well as on data about flora and vegetation. Unfortunately, in Russia, the latter are insufficiently, and more importantly, inconsistently, studied. This is especially the case for mires in mountainous territories.

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Use and Conservation of Mires in Russia

T. MINAYEVA & A. SIRIN

Abstract: The paper presents a general view on the history and current status of mire use and conservation in Russia. The geographical regularities of peatland exploitation follow the land paludification rate. In time, tendencies in mire use are connected to social development. Periods of intensive peat cut and drainage for forestry and agriculture cause overexploitation on one hand, and rapid development of peat science on the other. Peatlands that have been abandoned after use cause ecological problems like peat fires. One of the primary current threats to mires is related to construction and infrastructure development, including for the oil and gas industry. Through the present, mires have played a key role as source of natural resources for local communities. The conservation of mires and peatlands in Russia is still not integrated into territorial planning concepts. The mires can be found within protected nature areas and Ramsar sites, but very few of them were established exclusively to protect mires. Usually more mires are protected in higher paludified regions, where people are better acquainted with the mires. In southern regions, where mires are rare, they are less protected and human activity could cause them to disappear. Protected nature areas can not preserve all mires and support their functions, so wise use of mires should be the main strategy to protect them in Russia.

Key words: mire, peatland, peat cut, drainage, forestry, agriculture, hunting, nature conservation, protected areas, wise use, Russia

Introduction

Mires and paludified lands occupy 20% of Russia's total territory (VOMPERSKY et al. 1999). This means that mires and related ecosystems are responsible for natural and social processes on one fifth of the country's area. However, the role of peatlands and mires in Russian society has been very uneven in time and space.

The spatial diversity can be easily explained by the high heterogeneity of natural conditions throughout the country. In Western Siberia, the northeastern European part of Russia, and the Russian Arctic, mires are a natural part of human life. People were swathed in sphagnum at birth and buried in peat after they have died. People use mires as a resource in different ways and know no life other than that in mires. In steppe regions in the southern part of Russia, people had heard nothing about mires and peat for centuries. Mires there were destroyed years ago and now people do not care about how useful the mires might be for them today.

Changes in time are connected mainly with social processes, and depend on the availability of human resources and access to natural resources, especially fuel and standards of living. In the following short article, we invite you to take a look at different mire uses in space and time in Russia, focus on main threats, and assess how adequately mire conservation efforts are addressing those threats in our country.

Mire Use from Peter the Great to the Present

Mires are, on one hand, a source of various resources (peat, timber, medicinal plants, wild berries, mushrooms, etc.) and an important, though sometimes ambiguous, regulator of natural processes (river runoff, ground waters, microclimate, etc.). On the other hand, they limit tree growth, impede agricultural development in the area, and obstruct the establishment of transportation and other infrastructure. The history of man-mire interactions in Russia can be seen in the current status of mires across the

Photo 13: Drying harvested sphagnum moss in Mariy-El Republic, in the Volga region. Photo by T. MINAYEVA.

Photo 14: Capercaillie traps on upland midmire patches in Western Siberia are a popular massive hunting method used by the local population. Photo by T. MINAYEVA.

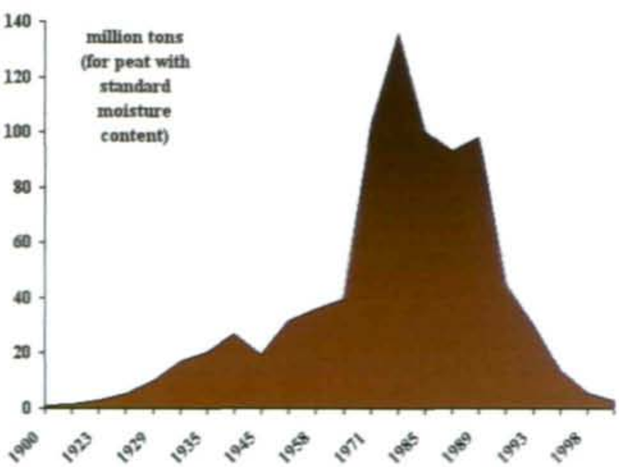


Fig. 8: Peat production in Russia (source: Peatlands of Russia ... 2001)

country's vast territory. Let us trace how these interactions have changed throughout the country's history to the present.

Harvesting Biological Resources

Mires have always been used locally for their biological resources (berries, mushrooms, game species, medicinal plants, raw materials), with varying intensity, depending on the region and time. Cartularies from the fourteenth century show that sphagna mosses were used in construction, as cattle bedding and even fodder. They also offer evidence that bog berries played a significant role in the monastic diet. Special sociological studies showed that people still regard mires as sources of vital biological resources. Picking cranberries, hunting moorfowl, and collecting moss for construction purposes remain essential parts of village lifestyles, even in industrially developed regions. In many highly paludifided northern and eastern regions, humans are even more closely connected to mires. Mires cover parts of indigenous peoples' tribal lands. There, they practice traditional nature use, which is sometimes very intensive.

The potential of biological resources is often immense. Annual production of sphagnum may reach 2.000–3.000 kg/ha. Berry yields may reach 300 kg/ha for cloudberries, 1.000 kg/ha for cranberries, up to 1.200 kilograms/hectare for blueberries, and up to 1.500 kg/ha for red lingberries (Peatlands of Russia ... 2001).

Difficult economic conditions in Russia during the last two decades have resulted in enormous pressure by berry pickers, especially near small towns in provinces where unemployment is quite high. Often, berry picking on mires is a very important, if not only, income of entire families. Consumer demand for medicinal plants has grown in recent years. The overuse of mire vegetative resources is becoming a problem in some cases.

Mires have long been regarded as special hunting grounds. Many game species are characteristic for mires in the forest zone:

the capercaillie, black grouse, willow grouse, some species of ducks, geese, and waders. Mires serve as a seasonal foraging base for mammals, especially ungulates, bears, and hares. Other species permanently settle in mire habitats, such as the beaver, two species of mink, and the otter. Often, mires, as less frequented areas, become refuges for animals (including game species) that move there from neighboring areas, which are intensively used by man. For example, mires and old peat extraction sites are actively colonized by typical meadow species, such as the grey partridge, quake, and corncrake. The fowl are followed by hunters, which cannot but cause concern. However, it is only in Siberia that hunting on mires has a large-scale character. Various traps and other hunting methods are used there, including shooting from helicopters. As a result, the local indigenous population, together with workers from oil and gas fields and inhabitants of industrial towns, pose a certain threat to species diversity on mires.

Photo 15: Lingonberries in a mire. Photo by A. SIRIN.

Peat Extraction

The practice of cutting peat for fuel has long been known, but it increases significantly in critical economic situations, when the country is oriented on local fuel types. Based on his experience in Holland, Peter the Great organized the first peat-burning factory in southern Russia, which was fixed in his decree from 1697. In 1766, LEMAN published recommendations for using peat as fuel. The first scientific study on peat in Russia was conducted by LOMONOSOV (1784), who described the macrofossil structure of peat and its characteristics as a fuel. SOKOLOV (1798) developed the first detailed scheme of a mire. During the same period, peat was already used as a fertilizer and a growing medium (FOMIN 1790). In the early nineteenth century, peat was widely used as a fuel, especially on railways, and as a soil improver.

During the civil war of 1917–1921, and during the period of foreign intervention against the young Soviet state, peat became a strategic fuel for the country, as access to coal and oil fields was closed. Peat fuel was a key starting point for the ambitious project to electrify Soviet Russia, which was developed by Vladimir Lenin. It was the only opportunity to promote the country's rapid development during those unstable times. Peat extraction steadily increased since that time until the mid 1980s, when it reached 140 million tons per year (Fig. 8). Peat winning methods have gradually changed: manual and partly mechanical peat-cut gave way to hydro peat production and, later, to milled one. In addition to the industrial peat win-

Photo 16: Mushrooms on a path along a forest drainage ditch. Photo by A. SIRIN.

Photo 17: Fields of milled peat production in Moscow oblast. Photo by T. MINAYEVA.

Photo 18: Local farms use peat to fertilize their agricultural lands. Photo by T. MINAYEVA.

Photo 19: An expansion of cotton-grass over a mined-out peatland. Photo by V. PANOV.

Photo 20: Sixty years after industrial hydro peat extraction. Photo by V. PANOV.

Photo 21: Abandoned and non-recultivated peat deposits in Vladimir Oblast. Photo by A. SIRIN.

Photo 22: In a small boiler-room in Novgorod Oblast, peat is used instead of coal. Photo by A. SIRIN.

ning for fuel and further processing, large-scale extraction for fertilizing was maintained by agricultural enterprises. They usually worked small fens often located in river valleys.

The increase in peat extraction promoted the development of the peat industry and studies on peat resources, structure, and deposits. Since the 1960s, research on, and inventory of, peat deposits became a part of the geological branch. This helped to standardize the collection, analysis, and storage of data on the exploration, mapping, and investigation of peat deposits; it also made the data more easily available for users and publications (Peat fund ... 1957, KHOROSHEV & KRESHTAPOVA 1979, OLENIN & KHOROSHEV 1983, SOKOLOV 1988).

The total area of mined-out peat deposits over the entire period of exploitation in Russia is estimated to range from 850.000 to 1,500.000 ha. According to the Land Cadastre, the total area of mined-out peatlands in 2000 measured a little over 240.000 ha. The rest of the lands were recultivated and transferred to other land categories (Peatlands of Russia... 2001).

Mined-out stretches of peatland deposits were to be recultivated for further agricultural use, afforestation, establishment of fishing ponds, or simply watering. However, the existing political stance towards the expansion of agricultural lands led to the dominance of this recultivation direction, which was often unreasonable from an economic and ecological points of view. At the same time, watering of worked-out peat deposits leads to the gradual, but slow, restoration of wetlands. Economic changes during the 1990s brought about a crisis in the peat industry. As a result, large areas of partly worked-out and non-recultivated peatlands were transferred to the so-called reserve lands, and thus became a constant source of potential fires.

In recent years, the attention to peat extraction has begun to increase again. In addition to the constant interest in peat as a fertilizer and raw material for further processing, there is a rapidly growing demand for peat as a fuel, primarily for local needs. Using peat for heating purposes has a number of positive ecological arguments in modern Russia. First of all, peat can be used instead of brown coal; the latter being is definitely a non-renewable fuel source, and much more harmful as far as air pollution is concerned. Secondly, in most cases, building up industrial peat extraction for fuel does not mean exploration of new peat deposits, and a renewal of work on abandoned peat plants would certainly decrease the danger of peatland fires.

Photo 23: Pasturing on peatland, which was previously used for local peat extraction in Tver Oblast. Photo by A. SIRIN.

Agriculture

Using peatlands as agricultural lands is typical for the central and southern regions of European Russia, southern Siberia, and the Russian Far East. Floodplain grass and black-alder mires and peatlands in forest steppe/steppe hollows and valleys have

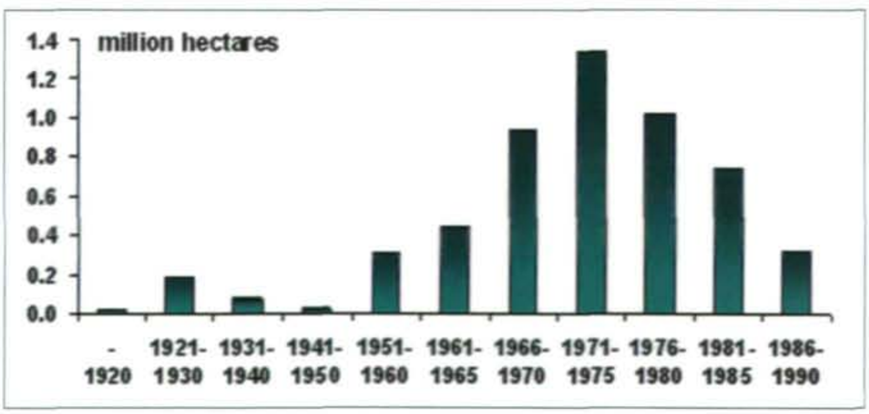
Photo 24: Growing vegetables on a drained peatland in Moscow Oblast. Photo by A. SIRIN.

Photo 25: Private gardens made on worked-out and recultivated fens often follow their contours. Photo by A. SIRIN.

mostly been destructed or transformed. The process of agricultural development of peatlands began in the late eighteenth century. Peat as a fertilizer was first mentioned in a Russian text in 1790. In the late nineteenth century, several plants, which manufactured peat bedding and fertilizers, were built in the Moscow Province. However, despite the considerable total volumes of annual peat production on the national scale, peat cut for agricultural purposes was, and has remained, a local-scale occupation, with simple equipment and low production rates.

Large-scale mire improvement to establish arable lands and hayfields began in the 1880s–1890s, under the authority of two well-known national expeditions. The western expedition was headed by General I.I. Zhilinsky and the northern one by I.K. Avgustinovich. After the expeditions were closed, provincial departments of agriculture and state assets carried out their tasks.

Fig. 9: Dynamics of forest drainage in Russia. (source: Peatlands of Russia 2001)



All in all, by 1917 amelioration work had been carried out on at least 3,000.000 ha of mires, the large part of which was meant for agricultural use.

Agricultural use of peatlands had a considerable positive impact on the development of peat science. Databases grew, research institutes were established, and journals were published. For the first thirty years, the inventory of peat resources in Soviet Russia was carried out by agricultural institutions.

Drained stretches on large peatlands were used as hayfields, pastures, and arable lands. In the 1970s, peatlands were used for small garden plots. This process was large scale in some regions, especially those close to large cities in European Russia. Fully or partially worked-out small peatlands were often used for this purpose. The floodplain mires, which were most valuable as far as their hydrology and biological diversity were concerned, sustained great damage during that period.

By 1967, the area of lands including mires in Russia that were drained for agriculture measured 1,600.000 ha, although it reached 5,100.000 ha by 1990 (Peatlands of Russia... 2001). Currently, most of them are inefficiently used or abandoned. In contrast to drained for forestry, secondary paludification seldom occurs there. The drained peat layer undergoes mineralization and combusts sporadically.

Forestry

Drainage for forestry is concentrated mainly in north-western and central European Russia; in the eastern Polessye at the border with Ukraine and Byelarus; in Karelia; and, to a lesser extent, in the Volga region and Cisuralia. Forest drainage has also been carried out in south-western Siberia.

Drainage for forestry was first mentioned in official documents in 1820, in the report of landowner Ivan PISKAREV to the "Forestry Promotion Society". That report stated that near St. Petersburg, PISKAREV had drained around 340 ha of peatland covered by dwarf pine and birch trees. More than 65 km of shallow ditches were cut, which resulted in the rapid height increment of trees by more than threefold. In 1844, the first documentation of a mire drainage project was prepared; the project was implemented on an area about 2.200 ha, also near St. Petersburg. In 1853, the government endorsed the practice of draining forested peatlands.

In the late nineteenth century, forests were actively drained together with agricultural lands and during road construction during the two aforementioned expeditions. The expeditions were conducted over a period of more than 20 years and covered the majority of the European part of Russia. Among other lands, drainage activity included 615.000 ha of forested peatlands. The income from forest melioration was estimated to be 1.06 million rubles. It was decided to develop further this activity. As a result, before World War I, over 850.000 ha was drained for forestry: 50.000 ha had been drained before 1870, while 800.000 ha had been drained during the period, 1870–1915 (KONSTANTINOV 1999).

The next period is characterized by the rapid development of the forest melioration theory. A number of background investigations and practical recommendations were developed (DUBAH 1945). Numerous scientific studies were carried out in connection to forest drainage and focusing on biological background (VOMPERSKY 1968), hydrology (VOMPERSKY et al. 1988, VOMPERSKY & SIRIN 1997), changes in biodiversity, and primary production (NITSENKO 1951, PLATONOV 1967, GRABOVIK 1989), etc. The discussion on the influence of forest drainage on the mire regulation functions were resulted in a number of publications (The role of peatlands... 1980, PYAVCHENKO 1985a) and in 1980th it was resumed that the drainage could have different impact on the catchment hydrology.

Forest drainage work was at its peak during the period 1966–1990. The area of drained forests exceeded 4,000.000 ha mainly in northwestern, western, and central European Russia. It was achieved through establishing special ameliorative plants that were economically interested in increasing work loads and decreasing expenses, including transportation costs. This did not promote selective drainage and resulted in con-

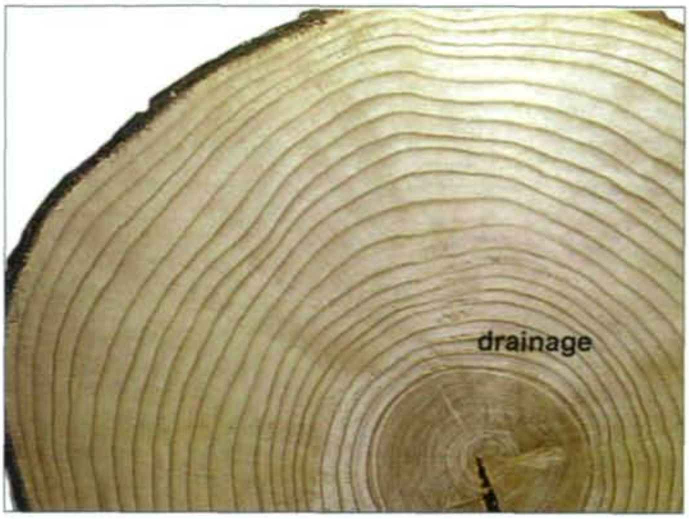


Photo 26: The increase in pine increment rate after forest drainage in Tver Oblast, in central European Russia. Photo by A. SIRIN.

Photo 27: A thirty-year-old forest drainage ditch. Birch trees have penetrated the dwarf shrub pine bog over excavated material. Photo by A. SIRIN.

Photo 28: Drains hamper the progress of peatland fires. Tver Oblast. Photo by S. VOMPERSKY.

Photo 29: A beaver dam in a forest drainage canal.

centrations of drained mires in distinct areas, often accompanied by a low efficiency of forestry. In general, however, this work helped to improve the forest management of the territories, to increase fire protection (due to the fragmentation of the area and building fire protection ponds), and to increase the accessibility of the territories for vehicles.

Unfortunately, at many reclaimed sites, no necessary forest-management activities were carried out, and therefore no economic effects were received. Drainage networks gradually deteriorated without maintenance work. This outcome was also promoted by the economic changes during the 1990s. According to the latest inventory (1999–2000), only about 3,000.000 ha of drained forests were registered in the European part of Russia. Most of the drained areas have undergone secondary paludification, often with the active assistance of beavers, the population of which has grown rapidly in recent years. This may even be positive from an ecological point of view; however, some drained forest areas, especially those with ripe spruce that have already begun to fall down, require the implementation of urgent forest-management measures.

Indirect Use: Life among Mires

When mires are all around, one has to explore, use, and transform them in order to eke out some living space. In highly paludified regions, most human impacts on mires can be attributed to so-called indirect use. An example of this use is the construction of transportation and other industrial infrastructure. In Russia, it is difficult (and in many regions impossible) to find a road that does not cross a mire. Standards imply building spillway facilities, but they do not support the natural flow of mire water, and an artificial concentration of it in the upper water by digging drains usually does not meet with the approval of engineering and environmental agencies. As a result, stretches of flooded and disturbed mires can be seen along most roads in Russia's forest zone. Drained stretches on the other side of roads are often less evident, but also present.

Similar impacts are caused by oil and gas pipelines that are laid not only in producing, but in other regions of the country. Unfortunately, the impacts of the oil and gas complex on mire ecosystems are not restricted to this and have many other manifestations (VASILIEV 1998). During the construction of drilling rigs, the mire surface is damaged physically and can hardly be recultivated. Adjacent sites degrade and lose their productivity and natural functions.

Oil production may cause pollution of the mire surface. Drilling oil wells usually involves the preservation of wastes in slime chambers, which are vessels of natural ground and plastic. If broken, they become massive sources of surface pollution by oil and related substances. Another pollution type results from spills of underground water rich in mineral salts that destroy all vegetation cover and promote the rapid degradation of the peat bed. Oil spills from broken pipelines are another pollution source. In addition to impact pollution, there is also carpet pollution that is spread by surface runoff or falling precipitation. This may lead

Photo 30: Seasonal houses in the endless mires in the Khanty-Mansi Autonomous Area, in Western Siberia. Photo by A. SIRIN.

Photo 31: The infrastructure of an oil-and-gas producing complex among mires in Western Siberia. Photo by A. SIRIN.

Photo 32: Trees that were flooded and died after the natural mire runoff was disturbed by a highway. Photo by A. SIRIN.

Photo 33: Disturbance of a mire after the pipeline laying in central European Russia. Photo by M. KRUCHIN.

Photo 34: Special vehicles totally destroyed the mire surface, Western Siberia. Photo by A. SIRIN.

Photo 35: A drilling rig in the mires of Western Siberia. Photo by A. SIRIN.

Photo 36: Pollution of mires after pipeline break in Western Siberia. Photo by A. SIRIN.

to a change in the trophic level of the mire, mineralization of peat, degradation of vegetation communities, and a decrease in the biological diversity.

Unlike some European countries, Russia does not widely develop and build up mires for national and municipal needs. In Europe this can be explained by the lower consumer value of paludified lands and by the presence of fewer land owners: these lands are often owned by the state and are therefore easier to alienate. However, in densely populated regions in Russia close to large cities, mires are more often build up, and their territories are converted to damping sites for solid municipal wastes and wastewater.

Incorrect mire use planning can have serious ecological consequences. Economic changes have a negative effect as well. In the early 1990s, large areas of partly worked-out and non-recultivated peatlands were abandoned in Russia. Many peatlands reclaimed for agriculture were no longer used. These lands became regular sources of fire danger. In recent years, methods of secondary watering of peat deposits have been actively applied to abandoned lands in order to trigger natural paludification.

However, the systemic and normative base of this work has not yet been developed. Watering is carried out, with varying success, by stakeholder institutions that use their own techniques and do not have any projects. Fire prevention is the greatest stimulus for their work. However, fires can also affect natural mires, due to the high visitor load during berry picking and hunting seasons. Peatland fires are a natural phenomenon in the boreal zone, including Russia, but the main reason for them in modern conditions is managerial faults.

Many mires in Russia remain nearly unaffected by economic activities. Such mires can be observed in Siberia, in the Russian Far East, and even in the European part of the country. Vast areas of mire ecosystems are not used directly. Some of them are protected. Nevertheless, many mires in those regions have be affected by human activity – via air pollution and other indirect influences.

Mire Conservation in Russia – Does it Meet Demands?

In Russia, mires and paludified lands were rarely mentioned as individual objects for conservation before the 1960s. With few exceptions (DOKTUROVSKI 1925, KATZ 1928), the issue of mire conservation was not even raised in mire science literature. At the same time, authors often cited mire's negative functions and advocated the necessity of large-scale mire reclamation and transformation (OLENIN & MARKOV 1983). Mires were protected indirectly, either as parts of specially protected areas or within the framework of the general regulation of nature use.

Conservation of Mires within Specially Protected Nature Areas (SPNA)

Due to the vastness of Russia's territory, the landscape approach has always dominated nature conservation planning (BORODIN 1913), and is reflected in historic conservation forms such as sacred grounds (groves), hunting reserves (menageries, etc.), as well

Photo 37: In dry years, fires may even affect natural mires, but stop before inner-mire pools. Kaliningrad Oblast. Photo by V. GUSEV.

Photo 38: Regeneration of mire vegetation after a peatland fire in Tomsk Oblast in Western Siberia. Photo by A. SIRIN.

Photo 39: Flooding mined-out peatlands is an effective way to prevent fires and, later, to restore the mire. Meschera National Park in Vladimir Oblast. Photo by A. SIRIN.

Photo 40: Volunteer conservation groups dam forest drainage canals, which is not always legal and ecologically sound. Novgorod Oblast. Photo by A. MISCHENKO.

as in current SPNA types, such as strict nature reserves (zapovedniks), national parks, and nature monuments. Mires and paludified lands were topologically included in these specially protected areas. Interestingly, one third of the Belovezhskaya Pushcha Nature Reserve, which was established in the thirteenth century by Prince Vladimir of Volyn, is covered by mires.

Scientific foundations of territorial conservation of mire ecosystems began to develop in the 1970s and 1980s. Criteria for identifying mires for conservation were developed (TANOVITSKY 1980), including those based on analyses of threats and positive functions (BOTCH & MASING 1979). Principles of complex resource utilization (Peatland resources…1989) were applied, including through prospective planning of the use and restoration of resources within every sector of economy (KUZMIN 1993), as well as by means of spatial planning (MINAYEVA 1996). MASING (1979) regarded mires as habitats of rare species, while ANTIPIN & TOKAREV (1991) presented the case for establishing specially protected mire areas.

Generally, territorial nature conservation in Russia implies establishing certain SPNA types listed in the Federal Law on Specially Protected Areas and in regional legislative acts that exist in some administrative regions of the Russian Federation. The Russian SPNA types partly correspond to IUCN classifications: zapovedniks are

Photo 41: Peatlands cover more than 75 % of National Park "Meschera". More than half of them were drained or partly extracted. That is why peat fires are the main problem for NP administration. Photo by A. SIRIN.

Photo 42: Mire ecosystems monitoring is the key activity within Nature Reserves and National Parks working programs. The permanent research staff is funded from the Federal budget. Central Forest Biosphere Reserve, Tver Oblast. Photo by N. ZARETSKAYA.

equivalent to the IUCN category Ia; national parks fall into the IUCN category II; biosphere reserves and landscape zakazniks are equivalent to IUCN category V, etc.

In Russia, the number of SPNA and the total territory they protect grown steadily in recent years, and now cover over 3% of the country's total area. Mire ecosystems have been protected within their boundaries, as have other landscape types (MINAYEVA & SIRIN 2000). In European Russia alone, zapovedniks and national parks include approximately 700.000 ha of mires, while federal SPNA in Siberia comprise as much as 3,500.000 ha of mires.

Many mires are protected in: Nizhnesvirsky Zapovednik (41%) in Leningrad Oblast (province); Kerzhensky Zapovednik (36%) in Nizhny Novgorod Oblast; Darvinsky Zapovednik (23%) in Yaroslavl Oblast; and in Vodlozersky National Park (42%) on the border of Karelia and the Archangelsk Oblast. However, these SPNA's were not exclusively established for mire conservation. At the same time, a number of nature reserves were established primarily for the conservation of mire ecosystems and corresponding plant and animal species.

To protect one of the largest intact raised bog massifs in northwestern Russia, two neighboring nature reserves were established in Polisto-Lovat mire system: Polistovsky Zapovednik (mires cover 71% of its area) in Pskov Oblast and Rdeysky Zapovednik (mires cover 92% of its area) in Novgorod Oblast. Yugansky Zapovednik was established in Khanty-Mansi Autonomous Area (mires cover 84.7% of its territory) to protect the famous Yuganskiye Mires in Western Siberia, which, moreover, are inhabited by the indigenous people of Khanty. The proportion of peatlands in Bolonsky Zapovednik in Khabarovsk Krai (province) also exceeds 80%.

A similar situation can be observed at sites having international protection status. Of the 35 Ramsar sites designated in Russia, none were established for the protection of mire ecosystems only (Wetlands in Russia ... 1999). Although, considering the special importance of these ecosystems for Russia, a shadow list of important peatlands was compiled (Wetlands in Russia ... 2000a). The list was coordinated on the regional administration level, which demonstrates the special position mires have in conservation planning in Russia's administrative regions. The fact that, although there are no Ramsar sites that were established exclusively for mire protection, over 9% of the existing wetlands of international importance (or 950.000 ha) are covered with mires and waterlogged lands (Wetlands in Russia ... 1999), offers evidence of mires' great importance. The large portion of peatlands presents in the Ramsar "Shadow List" of Russian Federation (Wetlands in Russia ... 2000b).

A certain portion of mires and waterlogged lands is protected within SPNA's of local importance: nature parks, zakazniks, and nature monuments. Many mires in various administrative regions of the Russian Federation have nature monument status. There is no special SPNA category for mire protection at the federal level, but in the 1980s, the administrations of some regions in European Russia introduced the "protected natural mire" SPNA type in order to implement sectoral resource conservation programs. The protected natural mires remained open for land use, but were excluded from timber felling and peat extraction for certain periods, according to business orders issued by the enterprises. However, this category did not receive further legal support. Many mires and waterlogged lands are located within game reserves (zakazniks). Their borders may be changed depending on the reproduction needs of the local game fauna. Game reserves regimes imply habitat conservation and therefore positively affect the status of the mires.

According to Russian legislation, lands within the aforementioned SPNA types of federal or regional importance and areas of limited land use (green belts of cities, etc.) are categorized within the Land Code as "nature conservation lands". Fig. 10 shows fractions of mires belonging to nature protection lands in different administrative regions of the country.

Mires are actively protected in administration regions where they cover large areas, play major roles in the social and economic life, and are often important research subjects. The latter promotes a further growth of (already relatively high) awareness of the local population, authorities, and other stakeholders regarding peatland management and conservation. These regions are northwestern European Russia (BOTCH & SMAGIN 1993), Western Siberia, and the Russian Far East.

At the same time, proportions of protected mires are modest in regions where mires naturally cover only small areas and have further contracted due to human impacts. This applies to central European Russia, including Moscow Oblast; most steppe and forest steppe regions of southern European Russia, Cisuralia, and Western Siberia; and the upland and mountainous regions of the Caucasus.

There is a certain subjectivism in the selection of mire ecosystems for conservation

Photo 43: The natural mires are usual habitat for numerous Orchids. *Platanthera bifolia* and *Dactylorhiza fuchsii* in mesotrophic mire in the Central Forest Biosphere Nature Reserve, Tver Oblast. Photo by A. DOBRIDENEV.

Photo 44: Spotted eagle (*Aquila clanga*) – extremely rare species all over Europe – found place for its nest in forested swamp, Taldom SPNA, Moscow Oblast. Photo by V. KONTORSCHIKOV.

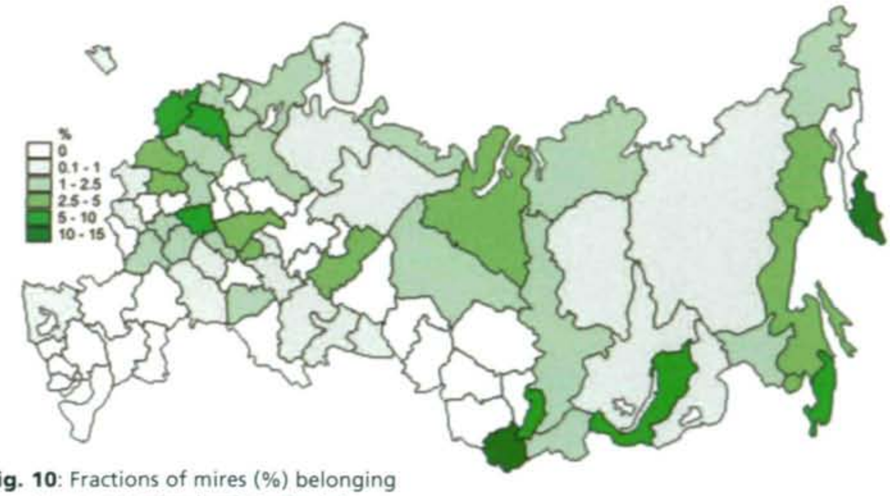


Fig. 10: Fractions of mires (%) belonging to nature protection lands in Russia's administrative regions (data from 1.01.2001, source: Peatlands of Russia ... 2001).

purposes. Traditionally, the greatest selection preference has been given to watershed raised bogs; spatial analyses of the inclusion of various mire types in SPNA's, which were carried out in European Russia offer evidence of this (MINAYEVA 1996, PREOBRAZHENSKY 2001). This can be attributed primarily to the long-standing delusion – and not only in Russia – about the especially important hydrological role of raised bogs, as riverheads etc. Scientific research has already proven the falseness of this selective assessment, but it remains deeply seated in the public consciousness. At the same time, fens (including floodplain mires) are still considered wastelands, regardless of their environmental role in regulating river discharge and protecting it from pollution, as well as of their importance in supporting floral and faunal biodiversity.

The "inequality" of different mire types in terms of their conservation can also be explained by their being belonging to different categories and having different statuses. The overwhelming majority of raised bogs are located on state-owned forest lands, which can be alienated or transferred to different land categories (e.g. those that allow more intensive use) only after numerous conditions, including ecological ones, are met. On the other hand, many fens, including floodplain mires, belong to agricultural lands that can be used or built upon with much fewer limitations. As a result, the very few floodplain mires remaining in natural condition have decreased and continue to decrease due to the construction of private homes and maintaining and other buildings. The possible way to overcome those contradictions is to integrate mire conservation concept into a perspective spatial land use planning process (MINAYEVA 2004).

Mire Conservation through Land Use Regulation

Foundations for regulating mire use were established in Russian practice from times immemorial. The protection of certain mire types was facilitated through traditionally quite strict nature management regulations that existed in pre-revolutionary Russia and in the Soviet Union, and which exist now. Back in the eleventh century, Yaroslav the Wise, the Grand Prince of Kiev, enacted the protection of forests and habitats of game animals, which are often associated with mires. PETER I issued royal enactments to establish water protection zones along rivers and floodplain conservation (REIMERS & SHTILMARK 1978, GRAVE 1993).

As it did in previous periods of history, national legislation is improving control over mire use, as well as providing for their conservation of mires within specially protected areas. Priorities in the field of mire conservation are gradually changing for the better, although perhaps too slowly. The legal base regarding mires has gradually been brought to rights. It previously had a lot of contradictions and discrepancies which reflected the traditional sectoral approach to mires and their resources (Peatlands of Russia ... 2001). According to current legislation, mires are water bodies with resultant consequences, such as the establishment of protective shoreline bands and water protection zones. Forests that grow on mires are regulated by the forest legislation, while peat extraction is regulated by legislation on the earth's interior. Furthermore, many federal legal acts on land, nature conservation, etc. also directly affect mires.

In the Soviet period, legal discrepancies concerning mires were partially leveled by the dominating state ownership of natural resources and lands. Nowadays, such legal discrepancies impede the regulation of economic relations on some mires, including their protection, and generate variant readings and errors in legal practice. For example, because of varying interpretations of water legislation, certain types of mires are not regarded as water bodies. In some areas of Western Siberia, all watershed mires are considered water bodies, while "sogra" mires (forest fens having high species diversity and unquestionable importance for water protection and regulation) are not. "Sogra" mires, therefore, lack the economic regulations provided by the water legislation. There is hope, however, that these discrepancies and errors will be gradually eliminated.

Despite the traditional presence in Russia of different sectoral views on mires, all of them accepted, to one extent or another, took into account the necessity of using mires wisely, including mire conservation.

Since the 1960s, the intensive utilization of natural resources associated with mire ecosystems and the general national support of the wise use ideology have promoted work to provide for the restoration of mire resources (PYAVCHENKO 1985b, Peatland resources ... 1989) as well as the importance of conservation of mire ecosystem diversity (NITSENKO 1962, BOTCH & NITSENKO 1971).

Since the 1970s, all legal acts and programs on mire improvement have examined approaches for the wise use of peatland resources. The *Torfgeologia* Industrial Geological Association, which is in charge of exploration for peat resources, assessed the conservation importance of peat deposits in European Russia (KUZMIN 1993). Botanical studies were carried out by the mire science section of the Botanical Society and by the *Telma* Group. The *Telma* Group was headed by Viktor MASING and Marina BOTCH, whose authority helped many regional administrators, land users, and resource users change their attitudes. By identifying mires for protection, the State Forest Service pursued a pragmatic purpose: to exclude low productive plantations from the total felling area. However, it is precisely these plantations that comprise the foundation of the modern network of protected mires.

With its traditional sectoral economic and scientific attitudes regarding mires, Russia needs an integrated approach to, and broad inter-sectoral collaboration in, planning mire conservation and wise use. An important step towards in this direction was made through the adoption of the inter-sectoral framework document, "Action Plan for Peatland Conservation and Wise Use in Russia." This document was developed as part of the implementation of decisions of the Ramsar Convention at the national level regarding the wise use of peatlands (Resolution VIII.17). To fulfill some of the major activity directions, which were adopted, a long-term project on peatland conservation was launched within the framework of the Wetlands International – Russia Programme. This project includes issues of national policy and legislation; international cooperation; methodic and informational support of mire conservation and wise use; information exchange; awareness raising; model field projects based on innovative and methodic studies; resolving 'burning' issues, etc. (http://www.peatlands.ru).

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The Great Vasyugan Mire

Abstract: The Vasyugan Mire is the largest mire system in the Northern Hemisphere and it has a long history of investigation. The article presents available information on the mire system's natural features, the history of its use, and current status. The overview of geological history and mire development in Holocene demonstrate the unique conditions. The mire system's location within two biogeographic zones and its vast size are the reason for its high biological diversity. The rich natural resources of the bog are attractive for people. The oil and gas industry, and drainage from forestry and agriculture have significantly affected the mire over the last twenty years. A wise use approach should be applied for land use planning. There is still not adequate information to fully understand natural processes in the mire and to avoid mistakes in decision making.

Key words: Russia, Western Siberia, Vasyugan Mire, history of investigation, mire landscape, mire vegetation, peat deposits, wise use.

History of Investigations and an Overview of the Vasyugan Mire

L. INISHEVA, O. LISS & N. SEMENOVA

The Vasyugan Mire, which, with a total area of over 5,000.000 ha is the world's largest mire, is situated in the watershed of the Ob and Irtysh Rivers (55°40′ – 58°60′ N, 75°30′ – 83°30′ E). It stretches for 573 km from west to east and for about 320 km from north to south (Fig. 11).

History of Investigations

The first fragmented data on the nature of the Vasyugan Mire appeared in the late nineteenth century, despite the fact that Russian naturalists had been to the mire much earlier (SHOSTAKOVICH 1877, GRIGOROVSKY 1882, 1884, PLOTNIKOV 1901). Natural scientist V.P. SHOSTAKOVICH, who traveled along the Vasyugan and Chizhapka Rivers in 1876, was one of the first to visit the area. His expedition was organized to explore probable reserves of gold and coal.

His report repeated an old legend about the Vasyuganskoye Sea; in fact, many earlier publications had depicted the Vasyugan Mire as a magnificent paludified lake/sea. One such example is the Draft Map of Siberia by S.U. REMEZOV, which included over 20 maps that were designed and printed in Tobolsk upon the of Peter I in

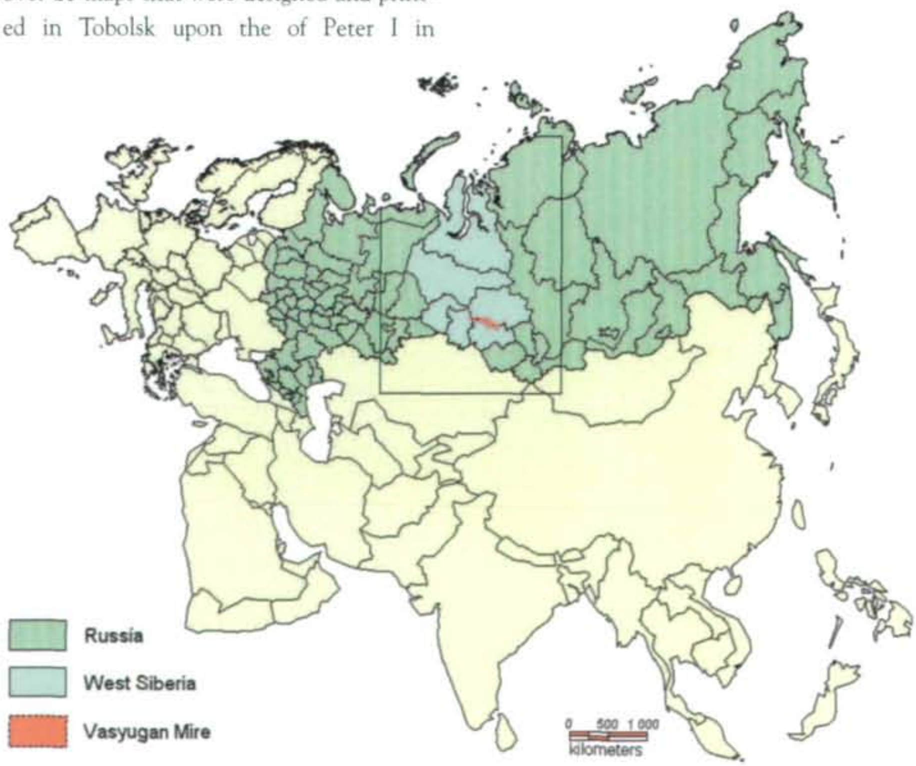


Fig. 11: Location of the Great Vasyugan Mire.

Photo 45: The Great Vasyugan Mire attracts researchers not only from Western Siberia, but also from all of Russia and abroad. Installations for gas flux measurements. Photo by A. SIRIN.

1678–1701. This document presented the Vasyugan Mire as a large lake from which tributaries of the Ob (KRYLOV & SALATOVA 1969) flowed.

In 1869, the Western Siberian Department of the Russian Geographic Society delegated N.P. GRIGOROVSKY to study the colonization of Siberia over the preceding 25 years. In 1908, the Immigration Agency of the Tomsk Region sent two parties to the Narym area. One of these parties, in which OTRYGANIEV & SBOROVSKY (1910) participated, followed an instrumental transect across the western portion of the Vasyugan Mire and along the Vasyugan River. Results of these works were summarized by PRAZDNIKOV & SBOROVSKY (1910).

Later, the Narym area attracted the attention of participants in soil and biological expeditions led by soil scientist D.A. DRANITSYN and botanist N.I. KUZNETSOV. These expeditions studied areas of Asiatic Russia that could be colonized. They made important descriptions of the topography and geological structure of soil and mires. DRANITSYN (1915) and KUZNETSOV (1915) concluded that the paludification of the area resulted from the expansion of mires over the land, which had been promoted by favorable climatic and orographic conditions and not from the overgrowth of hypothetical superlakes. These investigations fundamentally contributed to the scientific research of the Vasyugan area. They cast aside familiar legends about the existence of a great lake, which had even been quoted in scientific publications, as well as legends about fearless seafarers braving the Vasyuganskoye Sea, indigenous people crossing the mire on wooden bridges, and bears dragging heavy tree trunks to trample down fenny sites (1915, p. 22).

A Siberian expedition of the National Meadow Institute, which was led by A.YA. BRONZOV, conducted very important investigations of the mires in the Ob-Irtysh watershed. The results of these long-term (1925–1930) studies were published in BRONZOV (1930). The Siberian Immigration Agency assigned ILYIN (1930) to carry out mire studies in 1928.

During the period 1951–1956, Giprotorfrazvedka peat-exploring expeditions investigated mires in central Western Siberia to find peat deposits. The Vasyugan Mire was explored and studied during that period. The results of the expeditions were presented in subsequent publications (LOGINOV 1957, LVOV 1959, 1966, YASNOPOLSKAYA 1965, ORLOV 1968, Natural conditions … 1969, LYUBIMOVA 1972, ZEMTSOV 1976, LISS & BEREZINA 1976, 1981, Natural conditions … 1977, YEVSEYEVA 1990, ORLOVA 1990, Great Vasyugan Mire … 2002, The Vasyugan Mire … 2000, 2003).

Geology, Geomorphology, Genesis and Development

Almost all of the Vasyugan Mire is located on the Vasyugan tilted accumulative plain, which has a heterogeneous tectonic structure with positive and negative elements. Absolute elevations range between 116 and 146 m, with the maximum elevation being located at the headstreams of the Bakchar River. The topography is coarse, up to 0.6 km/km^2, with dissection depths below 10 m.

A comparative study of a map of the most recent tectonic movements and of the distribution of Western Siberian mires shows that the mires are distributed regardless of tectonic phenomena. Thus, the majority of the Vasyugan Mire is located in a tectonic uplift area. It seems paradoxical that brown moss-sedge fens are located at the watershed's highest point, at an altitude of 146 m. The fens may have originated at a lower surface, which was later raised by modern tectonic movement to a point above areas that are now occupied by raised bogs. However, it seems more probable that the mires emerged on a poorly drained upland with many saucer-like depressions, which became paludification nidi. As for the future, descending portions of the Vasyugan Mire will be paludified more actively than the ascending ones.

The rate of peat accumulation in the Vasyugan Mire during the Holocene Epoch has varied in different mire landscapes depending on the stratigraphic structure of the peat deposit. According to LISS et al. (1975), the accumulation rate equaled 0.5 mm/year in the early Holocene Epoch, 0.4–0.7 mm/year in the middle Holocene Epoch, and 0.88 mm/year in the late Holocene Epoch. KHOTINSKY et al. (1970) determined a near-bottom sample of a 4-meter-deep peat deposit in the eastern Vasyugan region to be 5.760±130 years old (non-calibrated ^{14}C dates), i.e. the mean annual increment equaled 0.7 mm. A peat deposit at the depth of 3.85 m was dated at 3.380±120 years, with the annual increment within the Holocene Epoch being 1.1 mm. A peat deposit at the depth of 1.75 m (4.570±170 years old) has had an increment of 0.6 mm/year. According to LAPSHINA et al. (2001), the age of lowest layers in the oldest peat deposits comprises 9.500–10.000 years. The ratio between the absolute age and the depth of the deposit is nearly a linear function in some of the large raised massifs in the southern part of the Vasyugan Mire, which are the northernmost counterparts of forest-steppe ryam mires, and which are formed by raised sphagnum peat almost all the way through the deposit. The long-term peat accumulation rate in these massifs reached a mean of 1.15 mm/year, but changed considerably with time. The linear peat increment did not exceed 0.6 mm/year in the first half of the Atlantic Period (6.000 to 8.000 years ago), but was as high as 2.6 mm/year on the edge of the late Atlantic and Subboreal periods. At the same time, the peat accumulation rate in extensive fens surrounding the raised bogs was two times lower (LAPSHINA & MULDIYAROV 2002, POLOGOVA & LAPSHINA 2002). The age of a fen peat deposit 2.8 meters deep proved to be 4.750±100, with a mean increment of 0.59 mm/year.

Simple mire systems merged at different stages of their development. However, the complex systems of the Vasyugan Mire were primarily formed during earlier stages of development. Hollows in the relief were filled with sedge-tree and *Sphagnum-Eriophorum* peat no more than 1.0–2.5 m deep. The rest of the deposit (7–8 m) is a homogeneous Sphagnum-peat, which proves that the mire system long developed as a single whole. According to KATS (1977), the Vasyugan Mire system graduated into the oligotrophic development stage as early as during the Boreal period of the Holocene Epoch, long before peatlands in European Russia did. It is possible that all topographic asperities were filled with peat even before the onset of the Boreal period.

Thereafter, some differentiation of peatland development is observed, with the

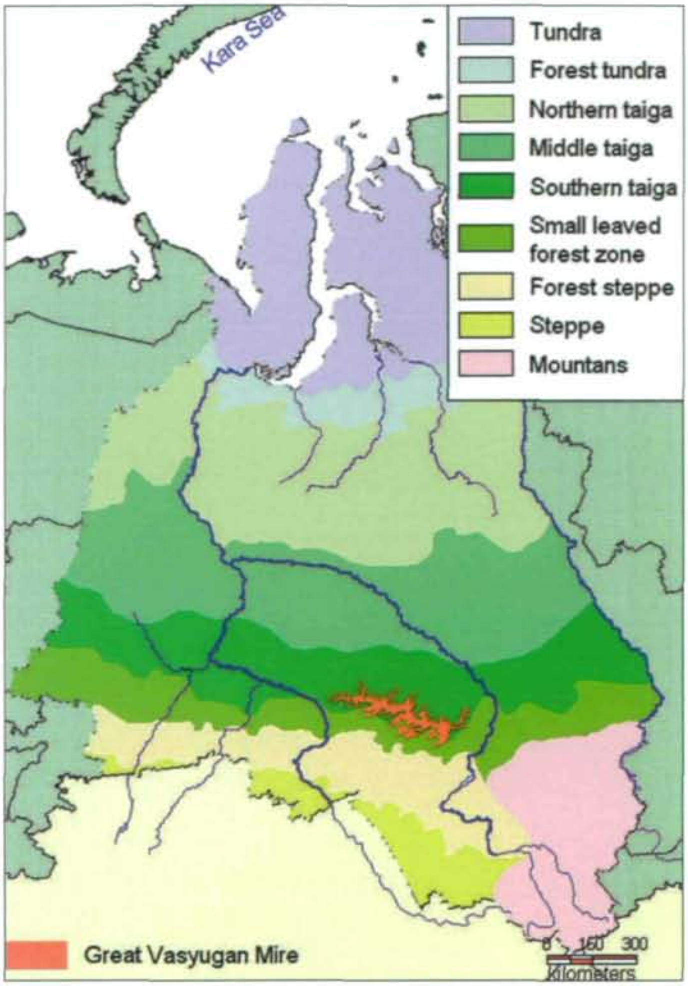


Fig. 12: The Great Vasyugan Mire is located in Western Siberia and between natural bioclimatic zones.

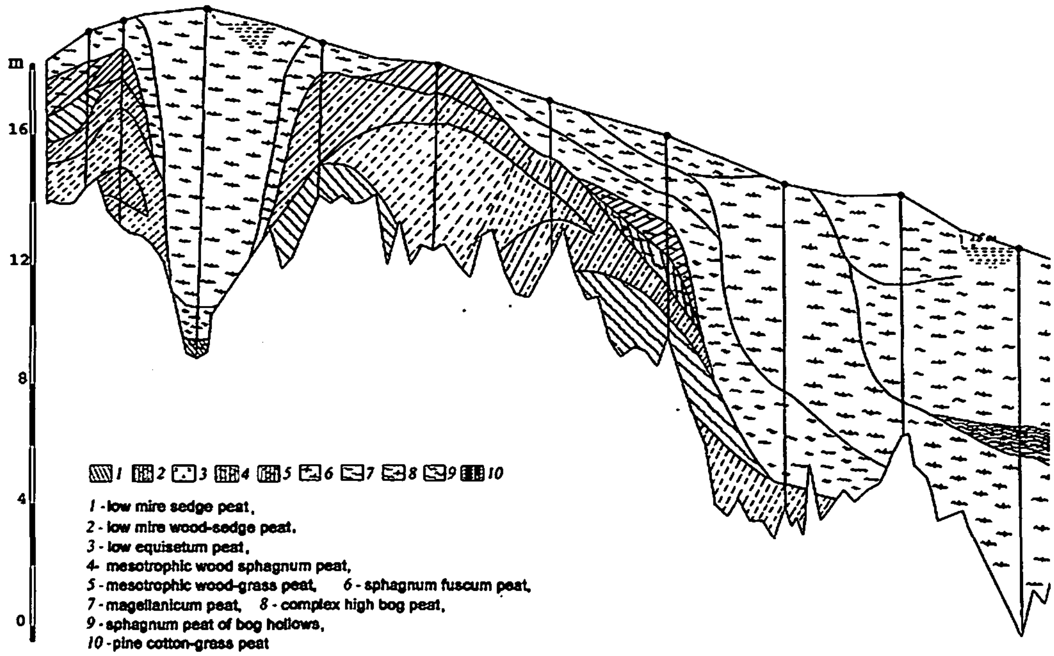


Fig. 13: The stratigraphic structure of the peat deposit profile located in the main watershed of the eastern part of the Vasyugan Mire (by L.I. INISHEVA).

stratigraphic profile of the peat deposit having the following pattern (Fig. 12). A more intensive peat accumulation takes place in the genetic centers of the mire system, while the periphery shows simultaneous lateral growth and an expansion of the mire area. This irregular and lopsided development of the mire results in it assuming a domed shape. Thus, the central portion of raised bogs within the mire system is elevated by 4 to 7.5–10 m above its edges or the surrounding fens.

As a result of the initial paludification of the Vasyugan Mire, it covered an area of 4,500.000 ha, including 19 sites (3,600.000 ha) with peat deposits over 0.7 meters deep. The remaining 900.000 ha are shallow sites with peat deposits less than 0.7 m deep. Presently, it is an integral mire massif, over a quarter of which was only relatively recently covered with peat.

The Spatial Structure of the Vegetation Cover in the Vasyugan Mire

E. LAPSHINA

The Vasyugan Mire system is a unique example of a diverse landscape of peatlands and paludified areas because of its vast size and location at the border of two botanical-geographic zones (Fig. 13). Various flat sedge-brown moss mires and paludified forests are typical for the small-leaved birch and aspen forest zone, i.e. the subtaiga. Oligotrophic Sphagnum mires are widespread in the southern taiga zone (KATZ 1971, ROMANOVA 1976, LISS & BEREZINA 1981). The low lixiviation of underlying layers, especially in the southern and southeastern portions of the Vasyugan lowland (YASNOPOLSKAYA 1965), is important, as often is the direct inflow of mineral-rich groundwater into the water and mineral nutrition of the mires is also important.

The primary watershed between the Ob and Irtysh coincides with the border of two adjacent botanical-geographic zones and divides the Great Vasyugan Mire into two parts: the northern part (northern spurs and the northern slope) and the southern part (mainly the southeastern portion) that differ considerably in their landscape structure and vegetation cover (LAPSHINA et al. 2000a, LAPSHINA & VASILIEV 2001).

The northern part of the Vasyugan Mire system is completely dominated by raised (oligotrophic) mire landscapes (Fig. 14). Flat-topped or (less often) slightly domed oligotrophic mire massifs, with a complex structure that resulted from the initial growth and later mergence of individual raised bogs, are typical for the center of the northern spurs of the Vasyugan Mire. These are bogs of the so-called Narym type, which

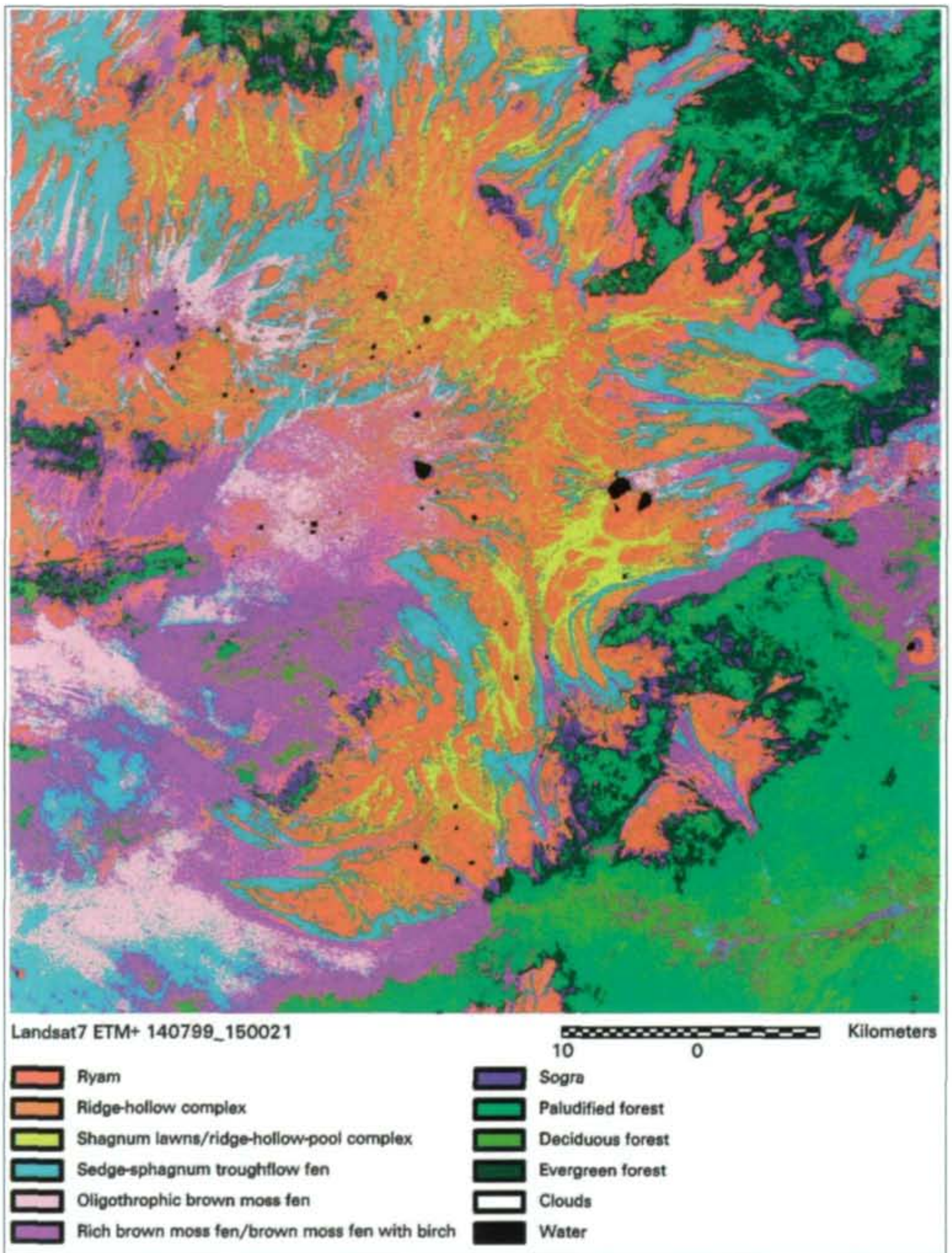


Fig. 14: A supervised classification of the Great Vasyugan Mire (eastern part – Iksa key area) prepared by Ananda BUESINK and Anne HOLLANDER with contribution from Elena LAPSHINA and Vladimir BLEUTEN (2002).

are typical for the Middle Ob area (BRONZOV 1930, KHRAMOV & VALUTSKI 1977, LAPSHINA et al. 2000a).

The most domed and relatively well drained stretches of the raised bog massifs are occupied by ryam mires, which is a Siberian term for pine-dwarf shrub-*Sphagnum* bogs with stunted pines. A well-pronounced tree layer of *Pinus sylvestris* is a particularity of ryam mires. Ryams are distinguished by the height of their tree layer, as well as the composition and structure of their ground cover. Typical (low-growing) ryams are comprised primarily of *Sphagnum fuscum* and their tree layer is 0.5–4.5 m in height. Tall ryams have a higher (6–12 m) tree layer of forest-like appearance and *Sphagnum angustifolium*, *S. magellanicum* dominate the ground cover.

Tall ryam mires form a broken strip 50 to 150 m wide at the border of typical ryam mires and forest mires at the periphery of peatland massifs. They cover a relatively small area. They are mostly after-fire restoration stages in place of typical ryam mires. The tall ryam has a flattened dome surface and its vegetation cover has a homogeneous structure. The tree layer is formed

Photo 46: Pine-dwarf shrub-sphagnum bog – a typical "ryam". Photo by E. LAPSHINA.

Photo 47: At the massif's periphery, where conditions among the "ryams" are more prosperous, individual cedar trees *Pinus sibirica* may be encountered. Photo by A. SIRIN.

Photo 48: An inner-mire island with a tall "ryam" in the middle of minerotrophic sedge-brown moss fens. Photo by E. LAPSHINA.

Photo 49: A hollow-ridge complex in the Great Vasyugan Mire. Photo by E. LAPSHINA.

Photo 50: A ridge-hollow-sphagnum lawns-pool complex in the middle of the flat surface of a well developed oligotrophic bog massif. Photo by E. LAPSHINA.

Photo 51: A ridge-hollow-pool complex. Photo by A. SIRIN.

by a tall-growing pine *Pinus sylvestris f. uliginosa* with an insignificant admixture of *Pinus sibirica* and *Betula pubescens*. The dwarf shrub layer is formed by *Ledum palustre* and *Chamaedaphne calyculata* with *Vaccinium vitis-idaea*, *V. myrtillus*, *V. uliginosum*. Forty to sixty percent of the ground layer consists of *Carex globularis*. The moss cover is closed, with a predominance of *Sphagnum angustifolium* and *S. magellanicum*. Other mosses, such as *S. fuscum* on elevations, *S. capillifolium*, *S. russowii*, and *Pleurozium schreberi*, are only sparsely present.

Typical ryam mires are considerably more widespread. They form an almost continuous band up to several hundred meters wide across the lower slopes of watershed raised massifs on the northern spurs of the Vasyugan Mire. The only occasionally occur in separate patches in the central part of raised mire massifs. *Sphagnum fuscum* dominates the ground cover and forms a dense moss peat. Other species are scarce, yet always present: *Sphagnum angustifolium*, *S. magellanicum*, *Mylia anomala*, and *Pleurozium schreberi*. The tree layer is diversely aged and consists of several paludal forms of pine (*Pinus sylvestris f. litwinowii*, *f. willkomii*). The shrub layer is dominated by *Ledum palustre*, *Chamaedaphne calyculata*, and *Andromeda polifolia*. Bilberries disappear, giving way to *Oxycoccus microcarpa* and, to a lesser extent, *O. palustris*. *Rubus chamaemorus*, *Eriophorum vaginatum*, and *Drosera rotundifolia* are frequent. Synusias of bushy soil-covering lichens are characteristic.

On the northern slope of the axial part of the Vasyugan Mire, ryam mires develop as mostly large (from several ten to several hundred meters across) drained patches within extensive raised massifs with complex structures. There, they alternate with ridge-and-hollow complexes and *Sphagnum* lawns, thus forming the surface's distinct mosaic landscape pattern.

In the northern part of the Great Vasyugan Mire system, the general landscape appearance of raised bog massifs is determined by various ridge-and-hollow, ridge-and-pool, and ridge-and-pool-and-fen complexes and extensive *Sphagnum* lawns with occasional ridges and pools. Covering the greatest area, they occupy gentle slopes and flat tops of oligotrophic peatlands, which are at mature stages of their development. Waterlogged *Sphagnum* hollows (lawns) develop in broad shallow depressions at confluence borders of elementary raised massifs. Intramire watercourses shaped like chains of small pools are often found there. The surface ratio of positive elements (ridges and ryams) and negative elements (hollows and lawns) can differ significantly. The vegetation cover of raised elements is represented by low-growing ryam communities; young secondary ridges still without a tree layer are occupied by dwarf shrub-*Sphagnum* communities (*Andromeda polifolia*, *Rubus chamaemorus*, *Sphagnum fuscum*).

The vegetation cover of diverse waterlogged *Sphagnum* lawns and hollows is formed by various Eriophorum-*Sphagnum*, Carex-Sheuchzeria-*Sphagnum*, and Rhynchospora-Carex-*Sphagnum* communities (*Scheuchzeria palustris*, *Carex limosa*, *Rhynchospora alba*, *Eriophorum vaginatum*, *E. russeolum*). They are predominated by oligotrophic *Sphagnum* species typical for hollows (*Sphagnum balticum*, *S. papillosum*, *S. jenseni*, *Sphagnum lindbergii*, *S. majus*) and liverworts (*Cladopodiella fluitans*, *Calypogeia sphagnicola* etc.). Liverwort-Rhynchospora communities, which have a close stand of *Rhynchospora alba* (40–60%) that is 5 to 10 cm tall, and which are dominated by *Cladopodiella fluitans* and thin sphagna mosses, are notable. Patches of bare peat mud occur in areas where marsh gases have recently been released. Narrow fringes of *Carex limosa* with *C. rostrata* and *Menyanthes trifoliata* develop around numerous pools and along watercourses.

In the landscape structure of large raised massifs (from 8 to 10–15 km across), diverse waterlogged oligotrophic mire complexes mostly resemble branched bands from several ten to several hundred meters wide, which descend from the central parts of the massifs towards their periphery. They are initial links in the natural drainage network, which provide a runoff of water surplus from the surface of raised bog massifs. The central parts of the bog massifs in the northern portion of the Vasyugan Mire are 3 to 4 m higher than on their periphery.

Photo 52: A bog lake in the ridge-hollow-pool complex. Photo by W. Bleuten.

Photo 53: A sedge-sphagnum through-flow fen ("galya") with *Betula nana, Carex rostrata, Sphagnum angustifolium, S. fallax, S. obtusum, S. majus*. Photo by E. Lapshina.

Photo 54: "Galya". Photo by A. Sirin.

Photo 55: Minerotrophic sedge-brown moss complex with ridges – "veretya-complex". Photo by E. Lapshina.

Photo 56: Minerotrophic sedge-brown moss complex with ridges – "veretya-complex". Photo by E. Lapshina.

Another essential element of the landscape structure of large raised bog massifs and their systems in the northern part of the Vasyugan region are extensive **poor transitional (mesooligotrophic) through-flow fen quagmires** known as **'galya'** in Siberia (Ilyin 1930). They transport water from mires to the river network. They are very conspicuous on satellite images due to their wedge-like shape. They abut the headstreams of rivulets and brooks, which flow from raised watershed bogs. The vegetation cover is relatively productive and represented by mesooligotrophic sedge-*Sphagnum* communities based on *Carex rostrata*, *C. limosa*, *Menyanthes trifoliata*, *Sphagnum fallax*, *S. majus*. The communities often include species that have greater mineral nutrition demands: *Equisetum fluviatile*, *Carex* *lasiocarpa*, *Sphagnum obtusum*. As for dwarf shrubs, *Betula nana* and *Chamaedaphne calyculata* are common; they form an open (5–15%) layer.

In the southern part of the Vasyugan Mire, the predominance of fens and transitional mires is characteristic of the landscape structure. The southern and southeastern portion are dominated by extensive **sedge fens, sedge- brown moss fens** and singular **veretya-fen complexes** with narrow ridges (veretya) perpendicular to the direction of the surface runoff or forming a typical reticular pattern on flat or slightly hollow stretches where the surface runoff is impeded. The presence of typical veretya-fen complexes with a reticular/polygonal structure has long been described as a particularity of the Vasyugan Mire (BRONZOV 1936, YASNOPOLSKAYA 1965, LAPSHINA et al. 2000a).

The vegetation cover of the brown moss fens is formed by sedge-brown moss communities with a predominance of *Carex lasiocarpa*, *C. omskiana*, and *C. chordorrhyza*. Less abundant, yet very often evident are *Carex limosa*, *Drosera anglica*, *Utricularia intermedia*, *Oxycoccus palustris*, *Scheuchzeria palustris* and *Rhynchospora alba* are less often evident. The moss cover primarily consists of *Scorpidium scorpioides* and sometimes *Warnstorfia exannulata*, *Meesia triquetra*, *Campylium stellatum*, *C. polygamum*, *Aneura pinguis*, *Riccardia hamaedrifolia*, *Bryum neodamense*, and *Pseudocalliergon trifarium* are present in small numbers.

Floating patches can form above water horizons buried in the peat deposit. They are large, round- or oval-shaped patches up to 30–50 m wide, which can be easily recognized by their vegetation cover. It is represented by sedge-brown moss communities of *Carex limosa*, *C. chordorrhyza*, *Menyanthes trifoliata* with fractional, yet persistent admixtures of *Carex diandra*, *C. heleonastes*, *Juncus stygius*, *Andromeda polifolia*, *Oxycoccus palustris*, *Utricularia intermedia*, and *U. minor*. The moss cover is formed by the same species as that in sedge-brown moss fens, with a total cover of 80-90%.

The veretya-fen complexes are formed by long and narrow ridges (veretya) that develop against treeless, waterlogged sedge-brown moss fens and occasional rounded 'islets' of ryam and tall ryam vegetation. Ridges 1–2 (3) m wide stretch across the mire slope for tens of meters. They rise only 10–25 cm above the fen surface, but are prominent due to their tree layer of birch and pine. Besides trees, the dwarf shrub layer is always present on the ridges. It varies from an open cover of *Betula nana*, *Andromeda polifolia* to well-developed cover dominated by *Chamaedaphne calyculata*, *Betula nana*, and *Ledum palustre*. The moss cover (40–80%) has a patchy structure. *Sphagnum warnstorfii* dominates in earlier stages of moss ridges development, with participation by *Aulacomnium palustre*, *Tomentypnum nitens*, *Sphagnum centrale*. At later stages, ridges are occupied by *Sphagnum angustifolium*, *S. magellanicum* and, finally, *S. fuscum*. Fens between the ridges are usually 50–200 m wide.

Large, flat *Sphagnum warnstorfii* hummocks that are 20–25 cm tall, and rounded or elongated in shape are characteristic of the vegetation cover of fen complexes. They emerge directly in waterlogged fens or abut existing ridges. The the hummocks' vegetation is formed by sedge-*Sphagnum* communities of *Sphagnum warnstorfii* and *Carex dioica*. An open, dwarf shrub layer consists of *Betula nana* and *Andromeda polifolia*; other characteristic species include *Carex chordorrhiza*, *Drosera rotundifolia*, and *Comarum palustre*.

Fen complexes and *Sphagnum* lawns cover extensive areas in the axial part of the Great Vasyugan Mire, descending in 'tongues' 2–3 to 20 km wide down its gentle southern slope. In the western part of the Vasyugan Mire, they alternate with large massifs of flat-topped, raised bogs and large domed ryam mires, in total covering about 30% of the mire system area (LAPSHINA et al. 2000a). The landscape role of fen complexes and *Sphagnum* lawns grows noticeably eastwards and especially southeastwards. There, they cover most of the area, alternating with occasional large and small domed ryam mires that are surrounded by 'tongues' of transitional mires channeling downward according to the direction of urface runoff.

Of great interest are rounded 'islets' of tall ryam mires ('shelomki', or 'helmets', in

Photo 57: A forest-like minerotrophic tussock sedge-herbaceous swamp ("sogra") on the northwest periphery of the Vasyugan Mire. Photo by E. LAPSHINA.

Photo 58: A rather typical "sogra" near a small stream draining the Great Vasyugan Mire system. Photo by A. SIRIN.

BRONZOV 1936) from 15(20) to 50(70) m across that form on tight, tree-dwarf shrub peat. They are actually remnants of frost mounds (palsa) that thawed and sank into the fen surface. They differ from the tall ryam mire in their more vigorous tree layer, which has abundant undergrowth that shades the *Sphagnum* cover and causes its partial degradation, a luxuriance of *Ledum palustre*, and the proliferation of green forest mosses. Patches of oligotrophic vegetation usually cover less than 1–2% of the area of the fen *Sphagnum* lawnss and veretya-fen complexes.

Larger raised bog massifs in the southern part of the Vasyugan Mire occur, as a rule, as domed ryam mires up to 3 km across or as groups of round or, more often, drop-shaped ryam mires that rise 7–8 (10) m above the surrounding waterlogged fens. Their vegetation is exactly the same as in the ryam mires in the northern Vasyugan Mire.

Transition (oligotrophic and minerotrophic) fens in the southern part of the Vasyugan Mire are unusual and peculiar. Having a mosaic and complex structure, they are formed in place of extensive fens and in fens with groundwater percolation that are surrounded by raised oligotrophic bogs. The diversity of vegetation communities on transition mires is relatively high and depends on the proportions of mire waters of different composition, which participate in the water-mineral nutrition of the mires. Typical among transition mires with poor mineral nutrition are **peripheral ryam fringes** and **mesooligotrophic flow-through fens**. The ryam fringes form around domed raised massifs at their junction with minerotrophic sedge-brown moss fens from several tens to 100–200 (500) m wide. The mesooligotrophic flow-through quagmires develop on the southern sides of large elementary massifs of domed raised bogs where acidic oligotrophic waters flow down their slopes. They are visible in satellite images, appearing as whitish "weather stains" with faint lengthwise striping and a blurred lower edge. The vegetation cover of these mires is dominated by sedge-*Eriophorum-Sphagnum* and dwarf shrub-*Eriophorum-Sphagnum* communities with *Betula nana*, *Chamaedaphne calyculata*, *Eriophorum vaginatum*, and *Carex rostrata*.

Forested mesotrophic dwarf shrub-paludal forbs-Sphagnum fens called locally **"yerniks"** and **birch-pine dwarf stands** develop relatively wide bands in contact zones between sedge-brown moss fens and domed raised bog massifs. They are also widespread in the lower portion of the southern slope of the Vasyugan Mire, where they form a broad broken band (up to 2–3 km wide). The yerniks and underwoods succeed sedge-brown moss fens and veretya-fen complexes located above them on the slope. They tend to develop at sources of elementary mire catchments and, judging by their position in the landscape structure, are similar to the above-described through-flow fen quagmires ('galya'), which are characteristic of the northern slope of the mire system. The vegetation cover is relatively homogeneous and consists of diverse forbs-*Sphagnum* communities of dwarf birch ("yernik"). A sparse tree layer (up to 5-10% of coverage) is formed by stunted pines and birches 3–4 m tall. The field and moss strata are formed by *Equisetum fluviatile*, *Comarum palustre*, *Menyanthes trifoliata*, *Sphagnum warnstorfii*, *S. angustifolium*; *S. centrale*, with a participation of *Carex lasiocarpa*, *C. chordorrhiza*, *C. magellanica*, and *Naumburgia thyrsiflora*. The moss layer always contains *Lophocolea heterophylla*, *Helodium blandowii*, and *Calliergon cordifolium*. The participation of *Chamaedaphne calyculata*, *Sphagnum magellanicum*, *S. obtusum* becomes more noticeable in 'yerniks' under conditions of poorer mineral nutrition.

The prevailing eutrophic sedge-brown moss stage that has continued until now in the southern Vasyugan area is associated with edaphic factors. Currently, a process of oligotrophisation can be observed on extensive fens of the Vasyugan Mire: young, actively growing ryam fragments form in the fen *Sphagnum* lawns. They are one to several (tens) meters across and rise 0.5 to 1 m above the water level. As the peat deposit grows, its structure becomes less influenced by the bedrock; the ash content of peat decreases; and favorable conditions for the sedge-brown moss phytocenoses are transformed into more oligotrophic structures. The regular development of frozen ground patches that do not melt in the summer, but persist over several years, is also important for the oligotrophisation of fens at the current stage.

Photo 59: Large cedars are not rare in *sogra*. *Photo by A. Sirin.*

The contour of the Vasyugan Mire system is fringed by an almost continuous band of forested swamps ('sogra'), from several hundred meters to 1–5 km wide. In Western Siberia as a whole, these swamps are mainly widespread on the floodplains of large and small rivers. On terraces and watershed plateaus, they tend to occupy the periphery of large mire massifs.

Mineral-rich ground waters are the main source of water and mineral nutrition in the area. Surface runoff and poor mire waters can also be of noticeable importance at a local scale. A phytocenotic diversity of forested mires is determined by paludification mechanisms, which, in their turn, depend on physical-chemical features of the ground and the inclines of adjacent slopes (Lapshina et al. 2000b). At points of contact with the low mineral shore, mire waters run over the surface, which leads to a eutrophic paludification of the forest and the development of rich paludal forbs-sedge tussock 'sogra' mires. Elevated shore stretches are often flooded with acidic oligotrophic mire waters, which leads to the formation of raised bogs and the development of tall ryam communities, regardless of the initial tree species and soils of the forests being paludified.

At the northern edge of the Vasyugan Mire, the paludification process involves

Photo 60: *Pinus sibirica* indicates rather high nutrition, which is supported by periodic fires in tall "ryam" sites along the boundaries of the Vasyugan Mire. Photo by A. SIRIN.

Photo 61: Tall "ryam" is usually formed after the fire restoration stage. Photo by A. SIRIN.

primarily zonal southern taiga forests, which then turn into dark coniferous paludal forbs-sedge tussock 'sogra' mires. Sedge tussock and paludal forbs-sedge tussock birch-pine 'sogra' mires form in place of birch and birch-aspen grass forests located on less leached and richer mineral soils. According to the tree layer composition, the mires are distinguished by their dark coniferous, polydominant, and birch-pine 'sogra' mires; less common are birch 'sogra' mires, which usually represent various pyrogenic forest mires (MULDIAROV & LAPSHINA 2000). A pronounced microrelief and abundant deadwood provide favorable conditions for small mosses and liverworts.

In accordance with the microrelief structure, the ground cover of 'sogra' communities is conspicuously patchy. Hummocks are occupied by mesophilous forest species: trees and shrubs (*Sorbus sibirica*, *Ribes* spp., *Lonicera* spp., *Frangula alnus*, *Juniperus communis*), dwarf shrubs (*Vacciniun vitis-idaea*, *V. uliginosum*, *Ledum palustre*), taiga forbs (*Maianthemum bifolium*, *Trientalis europaea*, *Rubus arcticus*, *Circaea alpina*), forest forbs and forest mosses of different ecological groups. Hollows between hummocks are overgrown by hydrophilous paludal plants *Menyanthes trifoliata*, *Thelipteris palustris*, *Equisetum fluviatile*, *Comarum palustre*, *Naumburgia thyrsiflora*, *Cicuta virosa*, small and tussock-forming sedge species *Carex loliacea*, *C. disperma*, *C. elongata*, *C. cespitosa*, *C. appropinquata* etc. Paludal mosses are represented by genera *Calliergon*, *Mnium*, *Drepanocladus*, *Calliergonella*, *Sphagnum* (*S. warnstorfii*, *S. centrale*, *S. squarrosum*) and many others.

The above sketch is a humble attempt to provide a general idea of the vegetation communities in the Vasyugan Mire. There are very few publications about the Vasyugan Mire that present a complete description of the vegetation cover, although a few sources are recommended (BRONZOV 1930, 1936, YASNOPOLSKAYA 1965, KHRAMOV & VALUTSKY 1977, LAPSHINA et al. 2000, LAPSHINA & MULDIYAROV 2002, LAPSHINA 2003). More extensive and detailed studies, which could probably be facilitated using new remote sensing techniques, are necessary.

Land use and Conservation of the Great Vasyugan Mire

N. M. SEMENOVA

Covering a vast area between the Ob and Irtysh Rivers, the Vasyugan Mire system affects human lives at various levels, from the local to the global one. It holds numerous natural treasures, such as peat, biological resources, and freshwater reserves. Its effects on processes responsible for water and gas balances in the atmosphere and on the formation of weather conditions cannot be exaggerated. The Vasyugan Mire holds over 5,100.000 tons of carbon, which comprises 12% of all carbon sequestrated in peat deposits in Western Siberia (or 4.4% for Russia on the whole).

The Vasyugan Mire is situated in the Novosibirsk, Omsk, Tyumen, and Tomsk administrative regions of Russia. With a maximum population density of 1 person/km², it is the least populated area of Western Siberia. Until recently, this area, which is located far from industrial centers and populous regions, was a *de facto* nature reserve, and nothing threatened its preservation. The indigenous peoples of Siberia seldom used mires in their traditional nature management. They practiced hunting and gathering only in the small peripheral parts of bogs that are adjacent to river valleys. As many Russians moved to Siberia in the 1920s–1930s, a number of small villages developed on the periphery of the Vasyugan Mire. The inhabitants were mainly peasants. Their subsistence occupations were and still remain gathering, hunting, fishing, and, less often, timber harvest.

The situation changed cardinally during the last three or four decades. The Vasyugan Mire area was exposed to considerable human impacts. It is now of economic interest, not just as a peat deposit, but primarily as an area rich in mineral and biological resources. The threat to the pristine natural landscapes of the Vasyugan Mire system makes it necessary to develop integral measures to organize sustainable nature management in the area.

Hunting

The Vasyugan Mire system is a wide migration corridor of biota and supports diverse habitats of typical and regionally rare animal species. The mire system is a stopover site for waterbirds and shorebirds during passage and other seasonal activities. Ungulates migrate across this area. The forests and mires of the Vasyugan region provide important habitat for rare and endangered animal species, such as reindeer, golden eagle, white-tailed eagle, peregrine, osprey, great grey shrike, eagle owl etc.

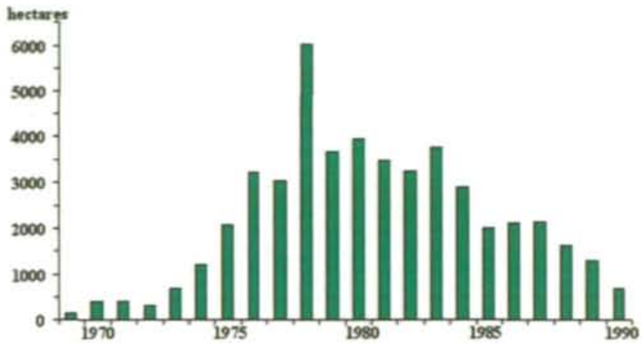


Fig. 15: Annual range of forest drainage in the Vasyugan Mire

Common commercial animals are elk, Siberian sable, squirrel, European mink, beaver, black grouse, hazel grouse, and willow grouse (VALUTSKY et al. 2000). Regularly licensed hunting is insignificant, and no serious conflicts between man and the nature have been recorded. Unfortunately, there have been incidents of illegal hunting using caterpillar vehicles and helicopters. These incidents are associated with the exploration of the area, when parties are sent to remote, difficult-to-reach areas of the mire to prospect for mineral resources.

Forest drainage

Forest reclamation was rather popular in 1970s and 1980s in highly paludified regions of Western Siberia. It involved large areas or extensive watershed mire systems, including north-eastern spurs of the Vasyugan Mire in the Tomsk administrative region, where forest improvement was started in the late 1960s. 128 ha were reclaimed by 1969, and efforts grew rapidly in the following years (Fig. 15). After 1978 the works were slowed down and completely stopped in the early 1990s. The total reclaimed area measured about 50.000 ha.

The reclamation efforts did not provide any noticeable economic benefits for forestry, but increased a danger of forest fires. Large forest fires took place there every year and sometimes affected over 300 ha. Virtually no reparation of the drainage network has been undertaken since 1990, which resulted in the secondary paludification of the forest.

Photo 62: A forest drainage collecting canal. Photo by W. Booren.

Photo 63: After forest drainage, a birch tree stand superseded former pine-dwarf shrubs-sphagnum ("ryam") vegetation. Photo by W. Booren.

Land Improvement for Agriculture

The location of the Vasyugan Mire falls in the precarious farming zone, but the south-eastern right bank of the Ob River in the Tomsk administrative region is favorable for farming. Therefore, land reclamation for agriculture was carried out in the 1960s-1980s at the eastern periphery of the mire. Currently, the reclaimed area covers about 11.000 ha, with 60% of the land occupied by hayfields, 34% by cultivation fields, and 6% by pastures. Most of the lands are still in use. Principal mire conservation objectives are: to prevent mire pollution with surface runoff from agricultural fields and to stabilize the groundwater table, which keeps the lands fire-safe and highly productive.

Peat Resources

The area of the Vasyugan Mire on territories of the Tomsk, Omsk, and Novosibirsk administrative regions is 5,269.400 ha, if measured along the zero depth of the peat deposit, or 4,863.400 ha, if measured along the minimal commercial depth of the peat deposit (The Vasyugan Mire ... 2000). In an estimation of natural resources of Western Siberia, paludified area of the northern stretch between the Ob and Irtysh rivers and part of the Tyumen Region were also included in the area of the Vasyugan Mire, which then comprised 7,300.000 ha. Peat resources are estimated at approximately 18.800 million tons (The geological structure ... 1998), which makes 15–20% of the total West Siberian resources. The peat resources have only been studied in detail in the area of 1,560.000 ha with a total resource of 4.815 million tons. Less than 1% of the explored peat resources are prepared for exploitation. Over a half of the resources (56.4%) are fen peat; 25.9% are bog peat, and the rest belong to transitional and mixed types.

Immense reserves and a diversity of raw peat types in the Vasyugan Mire waken sanguine hopes for its economic use. However, the peat reserves are dispersed over an extensive and sparsely populated area. Furthermore, deposits of low depths and high ash contents predominate in the mire system. This markedly restricts possibilities of an industrial development of the peat deposits.

Utilization of peat in highly paludified areas of Western Siberia has never been a priority. The peat was mainly used for agriculture. Currently, peat exploitation in the Vasyugan Mire area is insignificant. A utilization of peat resources, in particular those of the Vasyugan Mire, is a possible development trend for some regions of Western Siberia. However, it is necessary to introduce modern technologies, both in peat extraction and processing. Moreover, the extraction planning can only be carried out after a detailed estimation of the biosphere role of this vast mire system and an investigation of functional roles of its structural parts in the regional natural and economic system. An industrial peat extraction in the most (ecologically) vulnerable stretches of the mire may lead to irretrievable consequences.

Exploration for and Extraction of Mineral Resources

The Vasyugan Mire conceals immense mineral resources. Exploitation of them is associated with structural development, the construction of industrial facilities, the pollution of the surface with industrial waste, the destruction of the ground cover by caterpillar vehicles, and the permanent presence of people and other impacts. The greatest danger is unawareness about how important mire ecosystems are. One could speak about resource utilization and the simultaneous conservation of mire ecosystems' natural functions only as a result of awareness-raising activities and improved attitudes toward the mires. Legal measures should also play an important role in this process.

By now, the western part of the mire system up to approximately 81°E has been considerably transformed as a result of the development and exploitation of oil and gas fields. Resource exploitation is already permitted or applied for in the entire western part of the mire. Dozens of oil, oil and gas condensate, and gas deposits have been explored and developed there. Oil fields in the

Photo 64: Oil pollution of oligotrophic ridge-hollow bog vegetation near the bog lake. Photo by E. Lapshina.

southern Vasyugan group were developed in 1992, where the Chertalinsky Beaver Reserve ('zakaznik') that had existed for 20 years on 180.000 ha of the mire. The zakaznik's closure eliminated the possibility of establishing a strict nature reserve ('zapovednik') on the territory. A strict nature reserve had been proposed for creation there in the 1950s (Lavrenko et al. 1958) while a long-range plan to develop the geographic network of specially protected areas in Russia was being compiled. Prospecting work has started under a spur of the Vasyugan Mire to estimate the reserves of the Bakcharsky iron ore basin.

Conservation of the Vasyugan Mire: Status and Prospects

Currently, there are three zakazniks on the territory of the Vasyugan Mire. A botanical zakaznik of potential cedar forests, which covers about 65.000 ha of insular forest plantations predominated by Siberian cedar, is located in the Omsk Region. Two zoological zakazniks, Maizassky Zakaznik (85.000 ha) and Severny Zakaznik (106.400 ha), were established for the conservation and reproduction of beavers, minks, otters, and sables. They are situated in the Novosibirsk Region.

In the late 1970s, two sites within the Vasyugan Mire (in the watersheds between the Bakchar and Iksa Rivers and the Iksa and Shegarka Rivers, both in the Tomsk Region) were proposed for designation as nature monuments of regional importance, but no decision has been made so far. At the same time, these sites do not reflect all the landscape and biological diversity of the complex mire system. Projects of water protection zones have been developed for most oil and gas deposits in the Vasyugan Mire

Photo 65: A warning about the danger of peat fires. Photo by A. SIRIN.

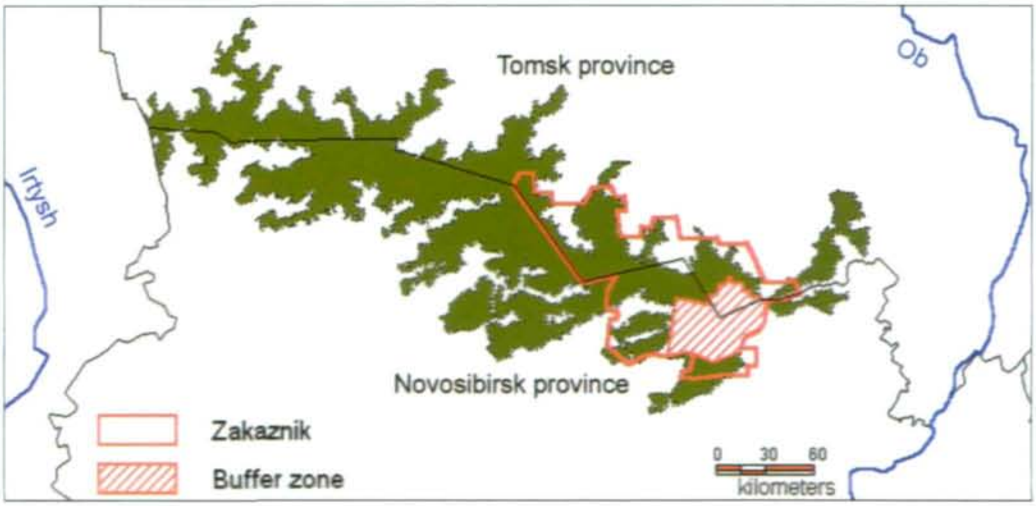
and in adjacent areas. They are established along rivers and brooks, as well as around mire stretches at headstreams and water-logged lotic mire landscapes.

In 1998, the Vasyugan Mire was included on the Shadow List of Wetlands of International Importance protected by the Ramsar Convention (Wetlands in Russia... 2000a, 2000b). According to assessments by Russian and western experts, the mire meets criteria as a UNESCO World Heritage Site. Should a specially protected area be established there within the framework of Russian legislation, an application may for submitted for this status.

With financial support from the Global Peatland Initiative (GPI), work to establish a landscape zakaznik in the Great Vasyugan Mire was carried out in 2002 and 2003. Special working groups, which included representatives of scientific communities and administrative structures, were formed upon the order of the governors of the Tomsk and Novosibirsk Regions.

Currently, three sites, covering 716.000 ha in total, have been approved for the establishment of a zakaznik on the Vasyugan Mire (SEMENOVA et al. 2002). It is an integral and representative fragment of the mire, which reflects characteristic features of the mire structure and the diversity of local landscapes, as well as their typical and unique objects/complexes (Fig. 16). In addition, its ecological and topographic situations are favorable, which would provide for the autonomy of the future zakaznik and for the preservation of its environmental functions. The sites selected for the zakaznik and its buffer zone have been excluded from prospective prospecting, extraction, and exploitation of mineral resources. There are neither prospected nor potential oil and gas deposits on territory of the planned zakaznik and its buffer zone. The establishment of the proposed specially protected area in no way encroaches upon the interests of the local population as far as traditional nature management is concerned. All materials concerning the creation of the zakaznik were

Fig. 16: The distribution of a planned specially protected nature area (zakaznik) in the eastern part of the Vasyugan Mire, in the Tomsk and Novosibirsk Regions.



submitted to the administrations of Tomsk and Novosibirsk Regions. The initiating group continues work to establish specially protected areas and looks for optimal ways to so, such as establishing a landscape zakaznik of regional importance (SEMENOVA & OGURTSOV 2003). For now, the conservation of the natural complex of the Vasyugan Mire is possible only through the strict observance of existing legislation in the field of nature management.

Conclusion

The attitude of people toward the Vasyugan Mire is determined by the fact that it is a unique natural phenomenon. We cannot stop the economic development. At the same time, we should improve our knowledge of nature, ecosystem functions, and the possible consequences of altering them. Our knowledge of the Vasyugan Mire is obviously insufficient for sound, long-range nature management planning on its territory. It is necessary to balance different forms of wise use. Possibilities of resource utilization depend on the abundance, availability, and quality of the resources, as well as on public demands. On the other hand, impacts on such a vast integral system may lead to local and global changes with unpredictable consequences. Therefore, decisions regarding the conservation and use of the Vasyugan Mire should be well balanced and based on scientifically proven facts.

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Inside Mires: The Nature and Current Status of Mineral Inner-mire Islands in Rdeysky Nature Reserve in Western Russia

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Abstract: Specific features of mineral inner-mire islands are described on the example of Rdeysky Nature Reserve, which covers the northern part of one of the largest Polisto-Lovat mire systems in western Russia. Mineral inner-mire islands are upland patches inside mires, which have overcome the accumulation of the peat deposit due to their elevated topographic position. Forest communities on mineral islands reflect the zonal features of the vegetation and, at the same time, are affected by the dynamics of the mire ecosystem. The inaccessibility of inner-mire islands protects their ecosystems from economic impacts and thus preserves them as examples of natural landscapes that were long ago modified outside the mire. However, during some historical periods, the islands' inaccessibility made them very attractive to people and gave a special touch to their interactions.

Key words: mire, bog, peatland, mineral inner-mire island, Polisto-Lovat mire system, forest, land-use, Russia

Introduction

Mineral inner-mire islands are upland patches inside mires, which have overcome the accumulation of peat deposit due to their elevated topographic position. Not exactly being mire ecotopes, they are unique objects both in the ecological and economic sense, as they reflect the interaction of the local landscape structure and the mire system on the one hand, and that of man and the mire as a complex natural-economic system, on the other hand. Forest communities on mineral islands reflect the zonal features of the vegetation and, at the same time, are affected by paludification processes that characterize the development dynamics of the mire ecosystem. The inaccessibility of inner-mire islands for man protects their ecosystems from economic impacts and thus preserves them as examples of natural landscapes that were long ago modified outside the mire. However, during some historical periods, the inaccessibility of the islands made them very attractive for people and gave a special touch to their interactions.

Mineral islands are inherent elements of the mire system that reflect its status and dynamics. Vladimir SUKATCHEV, an outstanding Russian biologist and mire scientist and a patriarch of biogeocenology, emphasized the importance of inner-mire islands for research on paludification processes. Many populations of animals inhabit mineral islands, which determines their conservation value.

The Mire System

The Polisto-Lovat mire system, which covers 90.000 ha, is a large massif of near-natural raised bogs and paludal lakes. In 1994, two state nature reserves (*zapovedniks*) – Rdeysky and Polistovsky – were established within its borders in order to facilitate the conservation and research of this unique massif of sphagna mires in the southern taiga of European Russia. Furthermore,

Photo 66: A small mineral island in the southern part of the reserve. Photo by author.

Photo 67: A buzzard nest on a mineral island. Photo by M. MYSLIVETS.

there are two additional specially protected nature areas within the mire massif: Rdeysky Nature Reserve (zakaznik) and the Lake Polisto Reserve (zakaznik) designated as a nature monument (Fig. 17).

The mire system is located on territory affected by the „Valday" (or Würm) Glaciation. The glacier flattened the surface, abating ledges and filling bays with foreign matter. After the glacier melted and the glacial lake receded, peat formation began in some depressions. Finally, individual mire massifs merged and created the present appearance of the Polisto-Lovat mire system. The area's current climate is temperate continental, bordering on maritime, with a surplus of precipitation, cool summers, and moderately mild, prolonged winters. The mean annual air temperature is +4.9 °C (Project… 1994). Abundant rivulets, streams, and lakes that form a very characteristic and important part of the landscape are typical for the mire system. The mire system feeds numerous rivers and streams, all of which belong to the Baltic Sea Basin. There are as many as 20 large lakes; three of them are located singly and the rest are clustered in groups.

The peat deposit in the mire system is very deep, sometimes reaching 7 m in depth. Over most of the area, the bog peat is underlain by a deposit of fen peat, which is 2–2.5 m deep, often with a thin bottom layer of sapropel or sometimes with a layer of

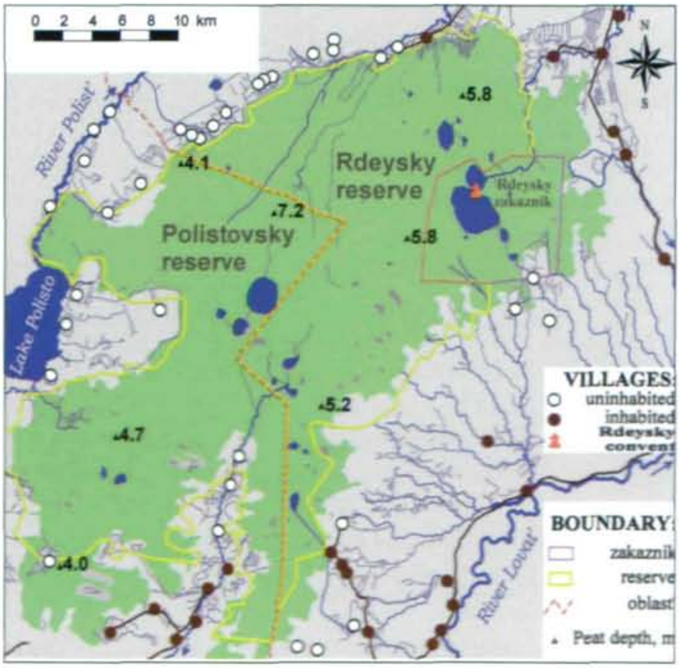


Fig. 17: Geographical position of the Polisto-Lovat mire system.

Photo 68: The shore of a secondary lake, which is located several kilometers away from the mire massif border. Photo by A. SIRIN.

Photo 69: Headwaters of a stream, one of many that begin in the mire massif. Photo by N. ZAVYALOV.

Phragmites peat. The fen peat and transitional peat seldom occur on the surface of the massif (TYUREMNOV 1976).

Being large in size, the mire massif promotes a diversity of vegetation communities. Most of the area is occupied by ridge and hollow complexes that vary greatly in the size of their ridges and hollows, their surface ratio, and their vegetation cover. Two groups of ridge and hollow complexes can be distinguished within the mire massif; the first one is dominated by *Sphagnum magellanicum* and the second one is dominated by *Sph. fuscum*. The second group is much more common. The tree vegetation on ridges is represented by the ecological form of pine *Pinus sylvestris f. Litwinowii*. The vegetation cover in hollows is more diverse, often with cotton-grass and *Scheuchzeria palustris* (BOGDANOVSKAYA-GUIENEUF 1969).

Equally widespread is the pool-denudation complex that occurs in central parts of the mire massif or that penetrates into other complexes in narrow strips. It covers only the combined *Sph. fuscum* – *Scheuchzeria* type of peat deposits. The upper layer of this deposit is transfused with veins of slowly flowing water that are the densest in the *Scheuchzeria* layer. The pool-denudation complex has a ridging microrelief, often with pools grouped into strips. Pines *Pinus sylvestris f. Willkomii* reaching up to 1 meter in height and *Pinus sylvestris f. pumila* 20–30 cm in height sometimes occur on the ridges.

Photo 70: The ridge and hollow complex is the most widespread microlandscape within the mire system. Photo by I. TARANETS.

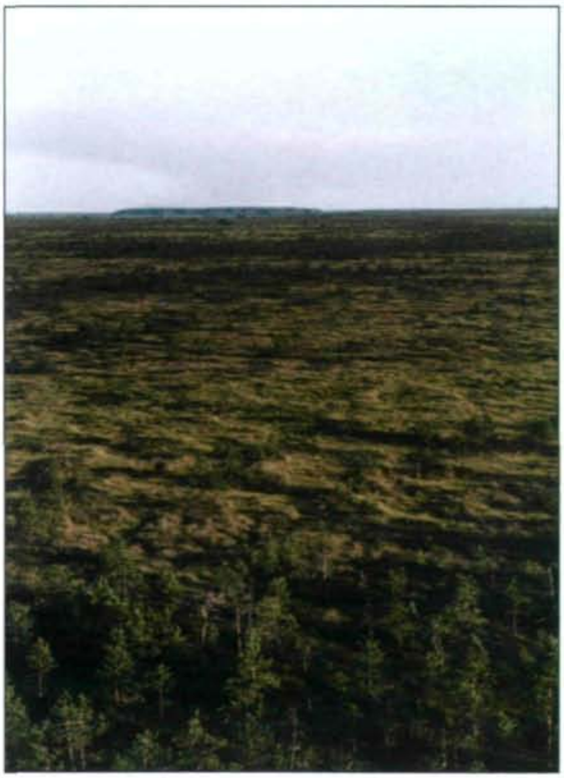
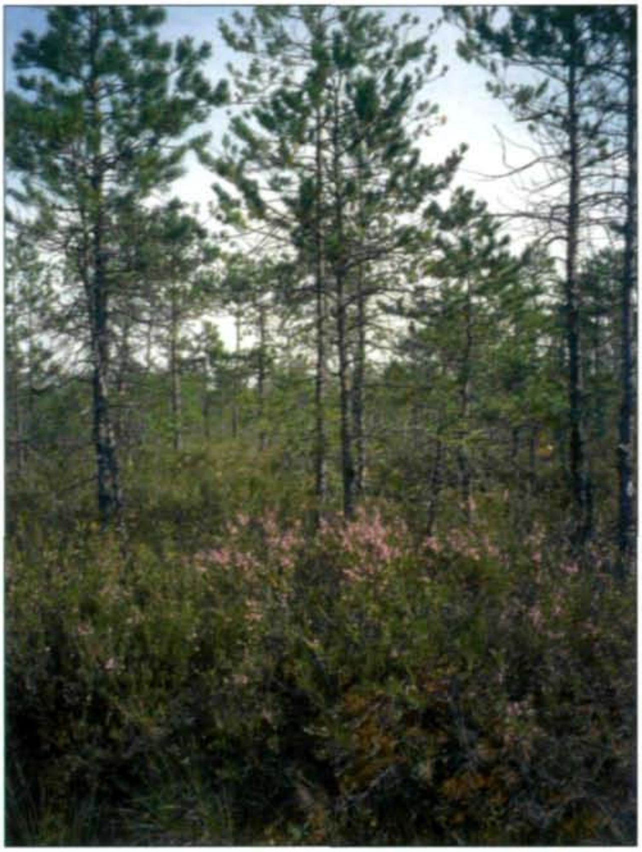


Photo 71: A top view of the ridge and hollow complex; a mineral island is visible in the distance. Photo by M. MYSLIVETS.

Photo 72: The Pine-Cottongrass-*Sphagnum* biogeocoenosis is widespread on drained patches of the mire system. Photo by A. SIRIN.



Because of the ridge degradation, aboriginal associations have been replaced by those with *Cladonia* lichens. Vegetation in hollows is usually formed by *Sph. cuspidatum* and later replaced by liverworts. Pools are round in shape, 5–8 m across, sometimes elongated, 15–20 m long, and 8–10 m wide. They vary in depth from 1 to 3.5 m (BOGDANOVSKAYA-GUIENEUF 1969).

Photo 73: Inner-mire islands are often flanked by impassable, waterlogged reed and sedge marshes. Photo by A. SIRIN.

The mire massif's well-drained elevations are occupied by top pine-sphagnum biogeocenotic complexes. The appearance of the complex is primarily determined by a wide distribution of the pine *f. Litwinowii*, ericoid dwarf shrubs, and sphagna mosses *Sph. fuscum* and *Sph. magellanicum*. Large portions of the mire massif are occupied by sphagnum transitional (*Menyanthes trifoliata*, *Scheuchzeria palustris*, *Eriophorum vaginatum*) mires. Characteristic features of this type of mire are an extremely even surface and virtually no trees (BOGDANOVSKAYA-GUIENEUF 1969).

Although they cover relatively small areas, pine-cottongrass-sphagnum biogeocenoses often occur within the mire system. They are associated with well-drained patches of small peat depth (with depths less than 2 to 3 m). The pine is represented with two paludal forms: *Litwinowii* and *Willkommii*. The pine-cottongrass-sphagnum biogeocenoses may develop as a result of the growing inundation and gradual deterioration of the pine forest by a sphagnum understory (BOGDANOVSKAYA-GUIENEUF 1969).

Some 200 vertebrate species inhabit the mire system, including fish (9 species), amphibians (3), reptiles (3), mammals (36), and birds (over 150). Eleven wader species nest in the mire, which supports the largest known breeding population in Europe of the Curlew. A number of bird species listed in the Red Data Book of the Russian Federation breed in the area, such as the Black-throated Diver, Black Stork, Golden Eagle, Spotted Eagle and Lesser Spotted Eagle, Ptarmigan, Golden Plover, Grey Shrike, and Eagle Owl. The European Mink is a rare mammal species inhabiting the mire system (PROJECT… 1994).

The Polisto-Lovat mire system has always attracted close attention from scientists. The first investigations were conducted during the period 1909–1914 in the eastern Pskov mire region. They were led by Vladimir SUKATCHEV and performed by his school: R.I. ABOLIN, A.R. KAKS, and S.M. FILATOV. Their observations of the Polistovo mires have retained their theoretical importance to the present day.

In the late 1920s and early 1930s, investigations of the Polisto-Lovat mire system were continued with funding from the Leningrad affiliate of the Peat Research Institute. Dmitri GERASIMOV and Sergey TYUREMNOV worked there at that time. Primary work on the investigation of the mire system was led by Ivonna BOGDANOVSKAYA-GUIENEUF. In 1969, she published a copious study on the formation of sphagna raised bogs exemplified in the Polisto-Lovat mire system; this study presented a summary of all previous research of the system.

Genesis of the Islands

An overwhelming majority of the mineral islands located within Rdeysky Nature Reserve (zapovednik) was formed by a subglacial moraine. They are shaped like single hills or are joined into ridges. In the northwestern part of the reserve, the mire massif is skirted by a ridge that consists of more or less oblong mounds that are divided by peaty channels. A few smaller ridges of the same orientation are located inside the mire massif. Islands formed by lake-glacial landforms include oses that stretch, similarly to the ridges, from southwest to northeast. Mound-like sandy islands formed of non-sorted sand with small boulders are not uncommon.

Native Vegetation of the Mineral Islands

Loamy sediments of the subglacial moraine are the most common in the composition of mineral islands in Rdeysky Nature Reserve. They are rich in nutrients that provide for the great productivity of the organic mass; if soil formation proceeds under a favorable combination of other soil factors, they also provide for aeration and soil humidity (ORLOV et al. 1974). Biogeocenoses on loamy soils are dominated by the common spruce or, in very favorable conditions, by the English oak.

Even a slight incline of the surface provides for good drainage and, consequently, for the formation of rich nemoral spruce forests. This forest type is very well represented on sloping mineral islands. The understory and sometimes also the tree stand are typically composed of broad-leaf species, while the herbaceous vegetation includes species requiring soil fertility. Forest plantations of birch and aspen develop there after human disturbance.

On smaller islands, where the mire may promote a special microclimate, forest stands are often composed of broad-leaf species, such as oak and linden. The plantations may consist of either oak or linden, or a mix of the two. Birch and aspen may also be present in the tree stand. Generally, growing conditions are far from optimal for broad-leafed species, therefore they are somewhat suppressed; many oak are dry-topped, with numerous frost cracks on their trunks. Because of regular felling, many trees originate from coppice shoots.

As drainage conditions of loamy soils worsen, the nemoral spruce forest gives way to a less productive spruce forest with a simple structure. It has a very dense stand, a crown canopy, and simple understories (ORLOV et al. 1974). Such forests occur on some flatter patches of the mineral islands.

Sandy islands, of which there are few in the reserve, usually develop two types of forest plantations: oxalis-bilberry pine forests and bilberry spruce forests. The pine forests form under favorable humidity and soil aeration conditions. They restore naturally very well, but are challenged by birch at felling sites and fire-sites. There, the birch appears earlier than the pine, suppresses the latter, and forms very productive stands (ORLOV et al. 1974). The development of bilberry spruce forests on sand can be explained by the high water content of the soil, which provides more or less favorable conditions for their growth (BEREZIN et al. 1969).

Human Impacts on Mineral Islands

During the last few centuries, a well-developed network of villages existed around the mire system (Fig. 18) and inner-mire mineral islands were regularly deforested for arable farming and hay harvesting. As late as the 1940s, inhabitants of Nivki and neighboring villages are known to have collected firewood on the nearest mineral islands. In fact, they crossed the frozen mire to reach Yelovik Island. The coppice origin

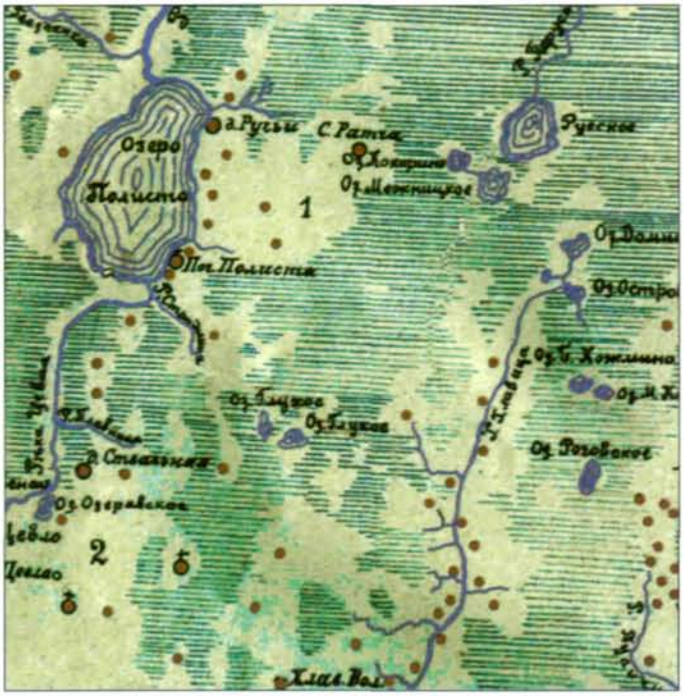


Fig. 18: Location of villages and farms around the mire massif on a map dating from 1905.

of oak and linden in forest stands is proof of earlier intensive felling. According to elderly local residents, treeless parts of the mineral islands were used for hay harvesting and for personal needs as recently as through the 1960s or 1970s.

The largest mineral islands were once inhabited. House foundations can still be found on Mezhnik Island, where a village of 18 homes was located before World War II. This small, remote community was likely to have been built by peasants who had fled the so-called military settlements established in the early nineteenth century by Count A.A. ARAKCHEYEV, an influential Russian statesman of the time. The inhabitants of the mineral islands farmed and raised cattle. In particular, they supplied butter to the royal court before the 1917 revolution.

For two years during World War II, the territory around the mire massif was occupied by German-Estonian troops. Remnants of dugout shelters that had used by refugees who had fled from villages destroyed in military actions can still be seen on many of the reserve's islands.

In recent decades, urbanization and the depopulation of villages around the mire system has led to a decrease in economic impact on the mire. However, these activities have not ceased altogether. Industrial timber fellings were carried out in adjacent areas. The mire massif was used for hunting, fishing, and berry picking. Cranberries have been collected industrially and their sale still remains a major source of income for the local population.

Lone islands that overlook the surrounding mire have prompted legends about treasure that was buried there. Holes dug by treasure hunters can be found on many of the islands. This activity was especially popular during the 1980s and 1990s. Before the reserve was established, the islands were a popular place for hunting. The remnants of hunting huts can still be found on some of the islands. On nearly all the islands, there are traces of tourist camps and fireplaces, which are in varying stages of being overgrown. In dry years, tourists can cause forest fires.

The magnificent ruins of the Cathedral of the Assumption can still be seen on an extensive mineral island next to the large inner-mire, Lake Rdeyskoye. The Rdeyskaya hermitage was established in the second half of the seventeenth century by hermits who had settled there and established a quiet, secluded community, which was mentioned in chronicles from the year 1666. By 1723, the hermitage possessed 301 serfs. The island was connected to the mire's shores by a log-road that could carry carts and wagons. Catherine II closed the hermitage in 1764 and converted it into a common parish. It was not until 1887 that the hermitage was restored as a convent thanks to the generous donations of a rich merchant, A.N. Mamontov. At the beginning of the twentieth century, a new cathedral that accommodated 750 people was built. It was decorated with stained-glass panels, wrought iron, and expensive materials. Especially rich and ornate was an iconostasis of imported Italian marble.

Many people called this region "a promised land" because the harvests gathered on the numerous mire islands were unusually rich. This can probably be explained by the special microclimate induced by the nearby mire. Local residents recall that in the 1960s an agrotechnologist from a nearby state farm grew grapes on a mire island that used to belong to the convent. Locals still pass down legends about very large cucumbers crops that were harvested by nuns who had used fish fertilizer made of small lacustrine fish abundant in Lake Rdeyskoye.

Local people believe that the old Cathedral of the Assumption has healing qualities. They claim that it exorcises demons from the obsessed and heals infertile women; thus, the convent island is very attractive to tourists. The restored Rdeysky convent will likely become a center of pilgrimage and ecological tourism.

Photo 74: The Cathedral of the Assumption, which belonged to the former hermitage that was located on an inner-mire mineral island. Photo by N. TKACHUK.

The Current Status of Island Ecosystems

Currently, most mineral islands in Rdeysky Nature Reserve are overgrown with relatively young, even-aged forests. The most widespread are birch and aspen forests, as well as secondary spruce and broad-leaf (dominated by oak and linden) forests.

A degree of human disturbance of the mineral island's mineral forest ecosystems is determined by two major factors: the remoteness of the island from the mire edge; and the character of mineral shores that determines the island's accessibility. Fig. 3 shows the northern portion of the reserve, with an elevated mire shore and numerous villages, both former and contemporary. In this situation, the safety of forest communities depends merely on the distance between the island and the mire shore. The adjacent mineral shores of the mire massif are also waterlogged and barely accessible. Therefore, there is no clear dependence between the degree of human impact on the islands' forest ecosystems and the distance to the mire shore.

However, disturbance by man is not the only disturbance that inner-mire islands face. The mire itself lays claim to the islands and, unwilling to leave them to either forests or to humans, it invades them slowly, but surely. Virtually all of the mineral islands are now paludified to a great degree; they vary from a slight suppression of the tree stand to its complete deterioration and a formation of a mire coenose in place of the forest one. The degree of disturbance depends largely on the topography and linear dimensions of the island.

The paludification processes that take place on mineral islands and around the Polisto-Lovat mire system were first studied by researchers of the eastern mire region of Pskov Province in the early twentieth century (KISLYAKOV 1905, FILATOV 1911). They believed that the reasons for paludification

Photo 75: A view of the mineral island and the hermitage from across the inner-mire lake. Photo by N. TKACHUK.

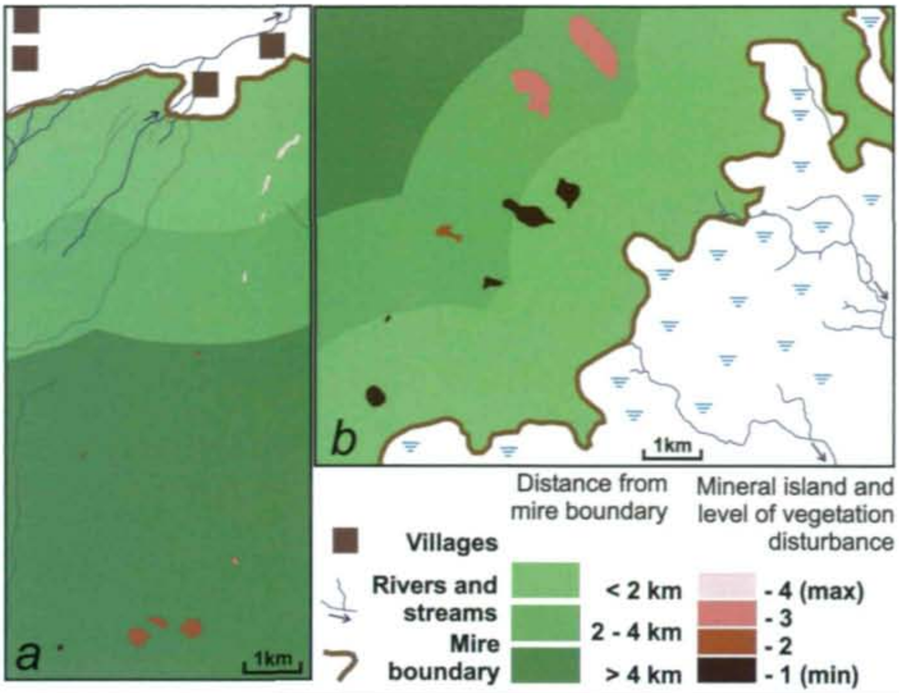


Fig. 19: The disturbance of tree stands on mineral islands versus distance to the mire shore.

were as follows: the construction of a waterlock in the eighteenth century on the Polist' River, which impeded runoff from the surrounding mires; construction of gristmills that increased the level of water in the river; and, finally, the silting of the river. However, BOGDANOVSKAYA-GUIENEUF (1969) showed that the main reason for the paludification is the mire system's natural development.

Photo 76: Beaver activity is one of the factors that supports the paludification process. Photo by N. ZAVYALOV.

Photo 77: Pines died as a result of paludification near the inner-mire island shore. Another island is visible in the distance. Photo by author.

Photo 78: A transitional tree stand of black alder and birch with reeds that have emerged on an inner-mire island as a result of paludification of its shore zone. Photo by author.

Photo 79: An oak forest on a mineral island that died as a result of paludification. Photo by author.

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