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Biotic diversity of Karelia:
conditions of formation, communities and species

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Biotic diversity of Karelia: conditions of formation, communities and species. A.N. Gromtsev, S.P. Kitaev, V.I. Krutov, O.L. Kuznetsov, T. Lindholm, E.B. Yakovlev, eds. Petrozavodsk: Karelian Research Centre of RAS, 2003. 244 p. 65 fig., 49 tab. 784 ref.

The monograph generalises vast data characterising the diversity of the biota in Russian Karelia. The data pool includes both materials of long-term studies, and new data collected in 1997–2000 within the Russian-Finnish project “Inventory and studies of biological diversity in Republic of Karelia”. The volume is composed of four interrelated chapters. Chapter one provides a detailed account of the climatic, geological, geomorphological, hydrological and soil conditions in which the regional biota has been forming. Chapter two describes and evaluates the diversity of forest, mire and meadow communities, and the third chapter details the terrestrial biota at the species level (vascular plants, mosses, aphyllophoroid fungi, lichens, mammals, birds, insects). A special section is devoted to the flora and fauna of aquatic ecosystems (algae, zooplankton, periphyton, macrozoobenthos, fishes). Wide use is made of various zoning approaches based on biodiversity-related criteria. Current status of the regional biota, including its diversity in protected areas, is analysed with elements of the human impact assessment. A concise glossary of the terms used is annexed.

This is an unprecedentally multi-faceted review, at least for the taiga zone of European Russia. The volume offers extensive reference materials for researchers in a widest range of ecological and biological fields, including graduate and post-graduate students. The monograph is also available in Russian.

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INTRODUCTION

The project ‘Inventory and study of biological diversity in the Republic of Karelia’ was initiated in 1997 by the Karelian Research Centre, RAS, as part of a finnish-russian development programme on sustainable forest management and conservation of biological diversity in northwest Russia. In order to carry out this cooperative venture a research team was formed involving of some seventy-five scientists from over twenty disciplines from the Forest Research Institute, the Institute of Biology, the Institute of Geology and the Institute of Water Problems in the North. The studies were coordinated by the Forest Research Institute and supervised by Dr. V. I. Krutov and Dr. A. N. Gromtsev. The project was funded by the Finnish Ministry of the Environment.

During 1997–2000 an inventory of biodiversity was performed in those parts of Karelia containing the most valuable flora and fauna (Fig.1), the best-preserved forest, mire and aquatic ecosystems and the most diverse biota. The research team worked 1) along the Russian-Finnish border (1997), 2) in the Karelian segment of the White Sea coast (1998), 3) in the Zaonezhye Peninsula (1999) and 4) in northern Priladozye (1999). This work continued in Central Karelia in 2000. The inventory thus covered a large and biologically most diverse part of Karelia.

By mid 2001 all the basic results of the 1997–2000 research had been published in four volumes containing a total of some eight hundred pages. In particular, a map of biotic diversity was gradually drawn up for several parts of the region. Similarly, the conditions of formation and the specific and cenotic diversity of regional biota were quantitatively and qualitatively assessed while the consequences of anthropogenic transformation were tentatively evaluated.

Published in both Russian and English, this monograph is an attempt to summarise all the material collected during 1997–2000 and to analyse extensive archives for the entire region. The monograph reports the results of the inventory of current regional biotic diversity. It consists of four interrelated chapters. Chapter 1 describes in detail the environments in which regional biota are formed. In Chapter 2 various terrestrial ecosystems (forest, mire and meadow communities) are discussed and assessed. Chapter 3 deals with the species diversity of terrestrial biota. The flora and fauna of aquatic ecosystems are analysed separately in Chapter 4. The monograph also includes a concise glossary of relevant terms.

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Editorial Board

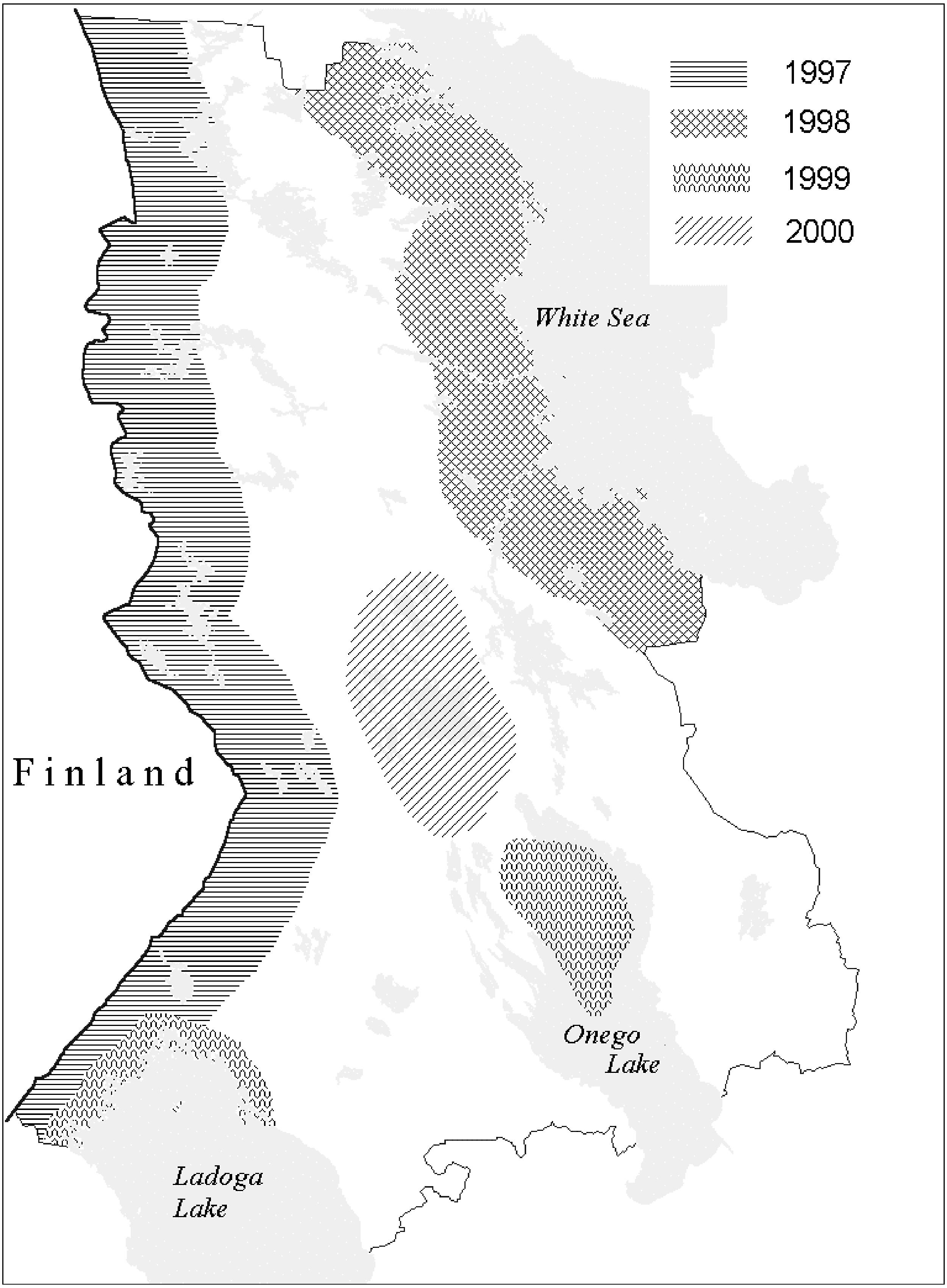

Fig.1. Areas covered by the inventory of biotic diversity of 1997–2000.

1. PHYSICO-GEOGRAPHIC CONDITIONS OF BIOTA FORMATION

1.1. Climate

Karelia is located close to the northern margin of the temperate climatic belt. According to B.P. Alisov's classification, the climatic system of the region marks a transition from a marine to a continental climate. This classification is based on the dependence of the formation of various types of climate on general atmospheric circulatory conditions. The climate of Karelia is part of the Atlantic-Arctic zone of the temperate belt. This means that air masses of Atlantic and Arctic origin predominate all year round.

The characteristic of the region are 1) a long but relatively mild winter; 2) a late spring with frequent cold spells; 3) a short and cool summer; 4) high relative air humidity; 5) a considerable amount of precipitation and 6) unstable weather conditions throughout all the seasons. This pattern is a consequence of a) the characteristics of the circulation system, b) the amount of incoming solar radiation, itself dependent on the geographic latitude of the territory, c) the proximity of the Baltic Sea, the White Sea and the Barents Sea, d) intensive cyclonic activity all the year round, and e) a variety of highly diverse local natural features such as relief, the abundance of lakes and mires, large forested areas etc. (fig. 2).

Precipitation. Karelia is located in a zone of excessive moistening. Its mean annual precipitation is 550–750 mm with precipitation increasing from north to south. However, the distribution of precipitation is also greatly affected by the orographic characteristics of the country as well as the character of the underlying surface. These factors tend to disturb the otherwise gentle gradation in variation of precipitation due to latitude . Thus, for example, total annual precipitation decreases markedly close to the White Sea and some large lakes such as Ladoga, Onega, Topozero (Tuoppajärvi) and Pyaozero (Paajärvi), etc.

Precipitation varies from 350–400 mm for the warm period (May-October) to 150–350 mm during the cold period. Over most of Karelia maximum precipitation is recorded in July, August and sometimes in September, when the monthly total varies from 70 mm in northern Karelia to 80–90 mm in other parts. Precipitation in the form of rain makes up 60–65% of the total annual figure, solid precipitation 24–25% and mixed precipitation 10–15%.

Humidity. Average relative air humidity varies from winter to summer from 90% to 50%. A humidity in excess of 80% is observed for an average of 150–170 days each year while values under 30% occur on only 3–9 days annually. Relative air humidity is highest during the cold period from November to January (over 85%) and lowest in May and June. However, even for these months average monthly values do not drop below 50–55%. During this period relative humidity in the vicinity of water bodies rises to 60% (70% on islands) in the daytime and 80% at night. Daily variations in relative humidity are seen most clearly during the warmer half of year (April – September). During this period relative air humidity maxima occur at 4–5 a.m. and minima at 2–4 p.m., the daily amplitude being 15–30%. During the winter season daily variation of relative humidity is not more than 1–5%.

As a result of substantial cloudiness, low summer temperatures, the high percentage of forest cover and high air humidity, Karelia lies in a zone of relatively low evaporation. Only fifty to sixty percent of atmospheric precipitates falling on the surface of catchment areas is lost through evaporation. The amount of moisture evaporating from the surface of soils decreases from south to north from 420 to 310 mm annually.

Winds. Southerly, southwesterly and westerly winds prevail all year round except in areas where the wind field is distorted by local relief. Thus, for example, near Kondopoga northerly and southeasterly winds are most common thanks to the influence of a chain of northwest to southeast oriented hills. The stability and velocity of winds depend on the season. As horizontal pressure gradients are high, winds are at their strongest (3–4 m/s) and most stable in direction during the cold period. Average monthly wind velocities range from 4–5 m/s on the open shores of large lakes to 7–8 m/s on the islands of Lake Ladoga and Lake Onega. During the summer season wind velocities decrease to an average of 2.5–3.5 m/s on land and 4–5 m/s on the islands. The daily variation of wind velocity is most clearly observed during the warmer part of year, particularly from May to August. Highest wind velocities are observed during the daytime.

Cloud cover. As a result of intense cyclonic activity significant degrees of cloud cover occur throughout the year. Average annual cloud cover is of magnitude 7 to 8 (on a scale where 10 indicates total cover). Cloud cover is densest during the autumn season with maximum values observed in November (magnitudes 8.8–9.2). During this period magnitudes of 8 to 10 occur with a frequency of 83–88%. The degree of cloudiness decreases markedly by March and average cover does not exceed 6.5 between March and July. As the sky is predominantly cloudy the amount of sunshine in Karelia is only 34–37% of its maximum potential (41–45% in the Leningrad, Novgorod and Pskov regions). Sunshine in Karelia displays a fairly uniform distribution pattern, increasing gradually from north (an average of 1560 hrs per year in Louhi) to south (1749 hrs in Sortavala). There are 140 days without sun in northern Karelia and 120–130 days in other parts of Karelia. From November to January sunshine is not observed for between 25 and 31 days each month. The number of sunny days during the spring and summer is much greater. June has the smallest number of days without any sun (one day on average).

Temperature. Mean annual air temperature varies from 0° C in northern Karelia to 3° C in southern Karelia. The coldest month is January (–12–13°C in northern Karelia and –9–10° C in southern Karelia). Close to large water bodies and on the islands of lakes Ladoga and Onega February is colder than January by an average of 0.2–0.5° C. Air temperature falls to –40° C once or twice every ten years and to –50° C once in 80–100 years. The coldest temperature on record for Karelia (–54° C) was reported in January 1940 in the Olonets district.

The warmest month is July (14–15° C in northern Karelia and 16–17° C over the rest of Karelia). The highest ever recorded air temperature is 36° C (July 1972, Pudozh).

The transition of mean daily temperature through zero degrees Celsius (the arrival of spring) occurs at the end of April in northern Karelia and between 10th–15th April in southern Karelia. Mean daily temperatures above 0° C persist for 175–190 and 190–200 days for northern and southern Karelia respectively. Cold spells are common during spring and snow cover is occasionally formed for short periods of time. By the end of April the snow has usually melted away from the entire territory. However, in northern Karelia snow may sometimes persist until the last ten days of May.

Summer (the stable transition of mean daily air temperatures through 10° C) arrives in late May in southern Karelia and in mid-June in northern Karelia. The average duration of the summer season is 2.5–3.5 months. The summer is both short and relatively cool. Stable periods of mean daily air temperatures higher + 15° C in northern Karelia occur only during warm years (provision less than 50%). In Central and southern Karelia this period lasts 30 to 50 days. Autumn comes in late August in northern Karelia and at the end of the first ten-day period of September in southern Karelia. Autumn lasts about two months.

Winter in Karelia is long although extremely cold temperatures are not common. Mean daily air temperatures below –5° C persist for 125–135 days each year in northern Karelia and for 115–125 days in southern Karelia. There are 70–80 and 50–60 days each year in northern and southern Karelia respectively when temperatures fall below – 10° C. There is no stable period of time with air temperatures below –15° C in Karelia. The transition of temperature through –5° C takes place in mid-November in northern Karelia and in late November in southern Karelia. The reverse transition occurs at the end of March in northern Karelia and between 20th–25th March in southern Karelia.

Fogs are commonplace in Karelia. They are most often caused by variations in air temperature and air humidity. The mean annual number of foggy days varies from 21 in the Padany area to 81 in Olonets. During some years the number of foggy days may reach 103. Fogs are least common between May and July (1–4 days per month) and most common in August and October (between 5 and 9 days each).

Thunderstorms are most common during the warm period from May to August. The first thunderstorms are very occasionally observed in April. Some years thunderstorms are reported in September and occasionally even October. Winter thunderstorms are extremely rare. Thus, for example, between 1949 and 1990 there were just three winter thunderstorms in Petrozavodsk (in December 1961, in January 1970 and in February 1968). Thunderstorms are most frequent in July (4–6 days). In some years there may be up to 15–18 days with thunderstorms per month. On average there are between 10 and 17 days with thunderstorms in Karelia each year.

Hail does not fall every year in Karelia and occurs chiefly during the warmer period (May – September). Hailstorms are usually accompanied by strong showers, thunderstorms and squalls. The average number of days with hailstorms per year estimated over a period of many years is 0.6–2.1. Hailstorms are most common in June. The largest number of days with hailstorms in any one year in Karelia (8 days) was recorded in Petrozavodsk in 1950.

Snowstorms occur in Karelia from September to June. The annual number of days with snowstorms varies from 25 to 55. Snowstorms become more frequent by the middle of the winter season and reach a maximum in January. This pattern is due to the coincidence of intense wind activity, a peak in the rate of solid precipitation and maximum dryness of snow. There may be up to 10–13 days with snowstorms and in some years even 20 days per month at this time of the year. By April the frequency of snowstorms has decreased substantially to 1–3 days per month. In northern Karelia snowstorms may occasionally occur even in June. Indeed, snowstorms were observed on one day in June at each of the Louhi, Yushkozero (Jyskyjärvi), Kem and Padany weather stations.

Tornados are extremely rare in Karelia. One particular tornado occurred in July 1972 near Yushkozero with wind speeds of 40 m/s recorded.

1.2. Geological characteristics

Introduction. The biodiversity of the region is significantly affected by two major factors. On moving from south to north there is a gradual decline in both the intensity of solar radiation and the complexity of geologic characteristics. Likewise, the number of species decreases considerably on moving northwards. Thus while Belovezhye National Park in Poland (54° N) is inhabited by over 2000 vascular plant species, Lahemaa National Park in Estonia (59° N) hosts 1200 species and the northern shores of Lake Ladoga (61–62° N) just 800 species. Only 420 species are known in Vodlozero National Park (62–63° N) and a similar number in the Kostomuksha Strict Nature Reserve (64° N) in Karelia while in Spitzbergen Svalbard(77–81° N) one may find no more than 150 vascular plant species. Although species diversity clearly tends to decline towards the north certain features occur which are not due solely to geographic location. Thus, for example, the Paanajärvi-Oulanka area situated close to the Arctic Circle (66° N) has a population of some 570–580 vascular plant species – almost a third as much again as that of the Kostomuksha Strict Nature Reserve 250–300 km to the south. Similarly, Vodlozersky National Park has about 420 vascular plant species while, just 50 km to the southeast, Kenozero National Park hosts some 700 species.

Areal non-uniformity is most apparent in the distribution of various rare species listed in the Red Data Books of East Fennoscandia (1998) and Karelia (1995) which require good growing conditions. In the geological sketch map (Fig. 3) dots indicate the location of 38 rare species occurring across the entire region. Certain species growing only in the southern (e.g. *Pulsatilla vernalis, Agrimonia pilosa, Ulmus glabra, Viola collina*) or northern (e.g. *Arnica alpina, Cotoneaster cinnabarinus*) parts of the region are not shown.

The localities at which rare species have been found form three closely-spaced clusters. These lie on the northern shores of Lake Ladoga, in the Onega synclinore and in the Paanajärvi-Oulanka area. It should be noted that these three localities all lie on Early Proterozoic volcanic-sedimentary rocks whereas the remainder of the region is dominated by Archean granite gneiss. According the Red Data Book of East Fennoscandia (1998) a lesser number of rare plant species is known within Finnish territory. Nevertheless, their habitats are also restricted to Early Proterozoic rock zones in synclinal structures occurring along the western boundary of the Karelian craton (near lakes Pielinen and Oulujärvi). Thus, the geological characteristics of any given area have substantial effect on its biodiversity.

Methods. Our studies in Paanajärvi National Park (Systra, 1998) showed that biological diversity is affected by the following geological and geomorphological characteristics of the study region: 1) the composition of the bedrock and of the Quaternary cover; 2) relief and orientation of landforms in relation to the cardinal points; 3) the occurrence of faults in the bedrock; 4) the occurrence of special migration corridors formed by macro-relief; 5) the drainage properties and colour of bedrocks and Quaternary sediments.

Other authors (Avtsyn & Zhavoronkov, 1993; Bogdanovsky, 1994; Ivanov, 1994, 1996, 1997; Thornton, 1983 et al.) have performed thorough studies of various chemical elements and showed that at least thirty elements must be present in the environment in the required concentrations in order for biota to exist and evolve normally. Eleven of these elements (C, H, O, N, Ca, S, P, Na, K, Mg and Cl) are macrobiogenic while sixteen others (I, Cu, Zn, Mn, Co, Ni, Mo, As, B, Se, Cr, Fe, V, Si, F and Sn) are microbiogenic. The physiological role of both the above mentioned and, indeed, all other elements is poorly understood. It is obvious, however, that biological life forms cannot diversify without a large-scale consumption of accessible macro- and trace elements from the upper part of the Earth's crust (Ecological.., 2000).

The influence of various geological factors on biodiversity was studied with regard to the geochemical characteristics of unevenly aged geological complexes located in Karelia and in adjacent territories. Lists of vascular plants and rare species from different localities were compared, links between rare species and rock composition studied, and geological and geochemical differences between localities differing in biodiversity identified.

Thus, for example, *Cypripedium calceolus* (L.) is restricted to carbonate rocks in northern Karelia, in the Kukasozero (Kuukaisjärvi) syncline and on the southern shore of Lake Tikshozero (Tiiksijärvi). These two sites are almost 30 km apart and the plant has not been found at other locations nearby. The carbonate rocks of the Kukasozero syncline comprise marine sediments while those from Lake Tikshozero are of Tikshozero magmatic carbonatite. Thus, the presence of a source of carbonate material is more important than the origination of the source.

Geological and geochemical characteristics of the study region. Karelia is situated in the southeastern part of the ancient Precambrian Fennoscandian shield (Fig.2). The part of the shield studied contains three large northwesterly oriented structural zones, namely, 1) the *Karelian craton* in the centre, 2) the *Belomorian fold belt* to the northeast and 3) *the Svecofennian fold terrane* to the southwest of the craton (Geology of Karelia, 1987; Systra, 1991 etc.).

The exposed part of the ***Karelian craton*** is 600 km long and 300 km wide. Its southeastern end plunges under *Vendian-Paleozoic sedimentary cover*. The craton has a two-storey structure. Its Archean basement is composed of Early Archean gneiss, granite gneiss and migmatite. These are cut by long, narrow greenstone belts consisting of Late Archean volcanic-sedimentary rocks. The second storey is formed by an Early Proterozoic folded volcanic-sedimentary cover which escaped erosion only in the deep-seated cores of synclines.

Archean and Proterozoic rocks vary greatly in geochemical characteristics. Silicon dioxide makes up 60–75% of Early Archean gneiss, gneissose diorite and granite gneiss. SiO_2 is dissolved by humus acids and accumulates in soil. Forming on such bedrock and covering over 60 % of the territory under study are acid soils poor in free Ca, Mg and many vital trace elements. Such zones are distinguished by the predominance of pine stands or mixed forests and the presence of typical taiga vegetation. Plants that require fertile soils and rare plant species are absent. Heterogeneous, highly metamorphosed gneiss and amphibolite zones are found in granite gneiss near Lake Kuito and to the northeast of Lake Vodlozero. These contain higher percentages of heavy metals and trace elements which occur, however, within silicate minerals and are not, therefore, readily available to the biota.

Narrow *Late Archean greenstone* belts are composed of sedimentary and volcanic rocks. These include high-MgO rocks, rocks rich in carbonate material as well as in B, As, Mo, Fe, Cr, Mn, Cu and many other elements. Associated with these rocks are deposits and occurrences of iron, molybdenum, gold and sulphide ores, etc. There the geochemical environment is more conducive to biota. However, botanists have not yet studied the zones where the above-mentioned rocks are exposed, e.g. Hizovaara Hill, lakes Keret and Tikshozero, the Hautavaara syncline, etc. Forests are dominated by spruce and grasses are more varied (the herb cover is richer in terms of species composition). Areas covered by greenstone belts are smaller than those occupied by granite gneiss.

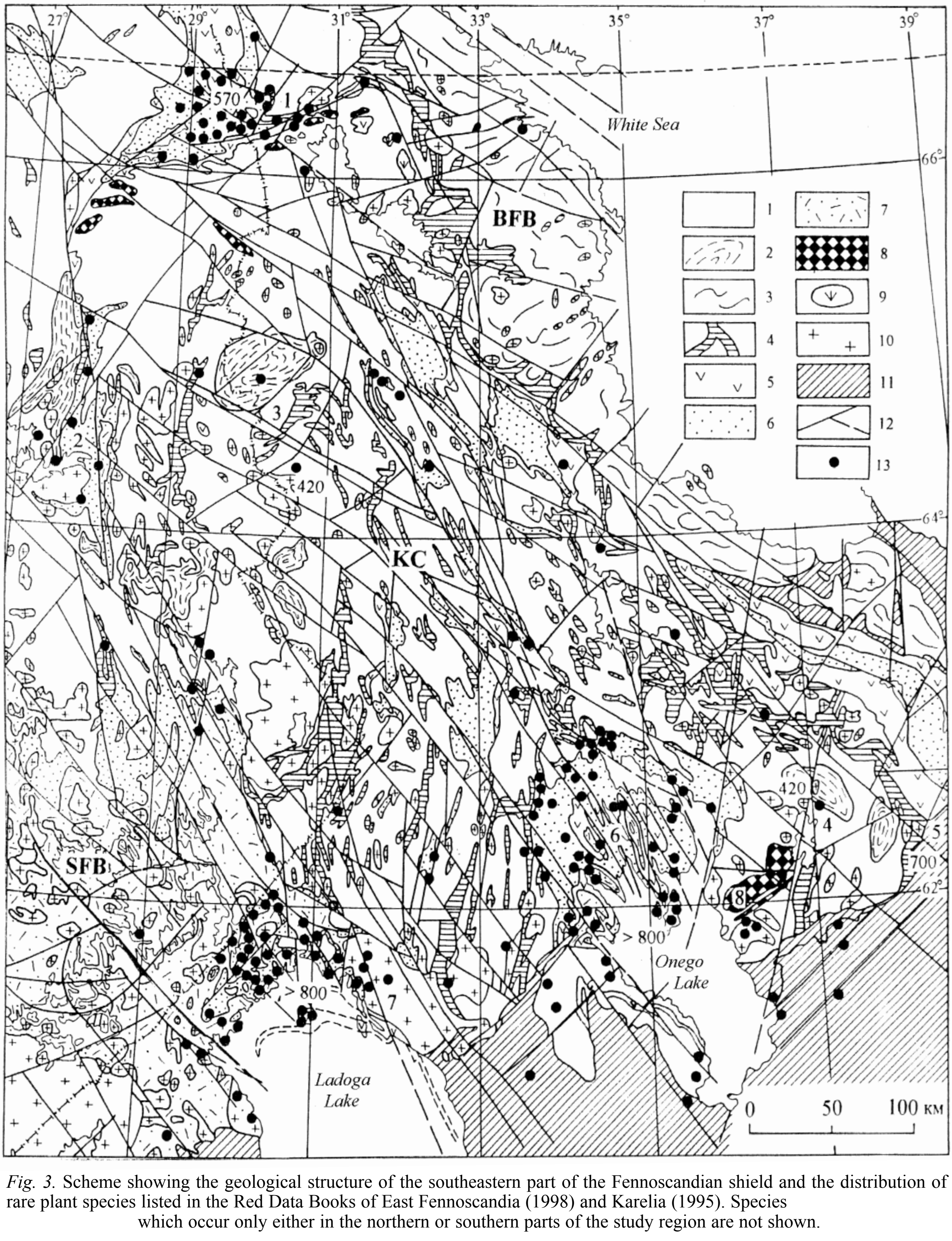

Fig. 3. Scheme showing the geological structure of the southeastern part of the Fennoscandian shield and the distribution of rare plant species listed in the Red Data Books of East Fennoscandia (1998) and Karelia (1995). Species which occur only either in the northern or southern parts of the study region are not shown.

1 = Early Archean gneissose granite, gneissose diorite and granite gneiss; 2 = Early Archean gneiss, migmatite and amphibolite; 3 = banded gneiss, amphibolite and migmatite (Belomorian fold belt); 4 = Late Archean greenstone belts; 5–6 = Early Proterozoic folded cover of the Karelian craton: volcanics (5) and sedimentary rocks (6); 7 = flyschoidal sediments (Svecofennian fold terrane); 8 = layered peridotite-gabbronorite massifs; 9 = gabbro-alkaline massif; 10 = granite; 11 = Vendian-Palaeozoic platform cover; 12 = major fault zones; 13 = habitats of rare species. **KC** = Karelian craton; **BFB** = Belomorian fold belt; **SFT** = Svecofennian fold terrane. Single-digit numbers indicate: **1** = Paanajärvi-Oulanka area; **2** = Oulujärvi area; **3** = Kostomuksha Reserve; **4** = Vodlozero National Park; **5** = Kenozero National Park; **6** = Onega synclinorium; **7** = Northern Priladozhye; **8** = large Burakov layered peridotite-gabbronorite massif. Three-digit numbers indicate the number of vascular plants found.

The *Early Proterozoic folded volcanic-sedimentary cover* has only survived in the form of a number of relict zones. These are located 1) along the Karelian craton boundary in the Paanajärvi-Oulanka area; 2) in the Kainuu schist belt near Lake Oulujärvi; 3) on the northern shores of Lake Ladoga; 4) in the Windy Belt synclinorium; 5) in the Lehta structure; 6) in the Yangozero, Onega and Haikola synclinoria located in the central part of the Karelian craton; as well as in the Voloma, Segozero, Suojärvi and Chirka-Kem synclines and in certain smaller structures (Systra, 1991). These volcanic-sedimentary rocks are more diverse in composition. Felsic, intermediate and mafic volcanics, quartzite, sandstone, carbonaceous rocks and shungite-bearing black schists etc. are all of common occurrence. Associated with them are complex U-V, titanic iron and copper ores, base-metal occurrences, etc. The rocks typically contain high percentages of Ca, Mg, heavy metals and trace elements (Golubev & Systra, 2000). In the central parts of the large Kuolajärvi (Paanajärvi-Oulanka area) and Onega (Zaonezhye Peninsula) synclinoria as well as along the northern shores of Lake Ladoga, where the glacier moved over Proterozoic rock for a lengthy period of time, moraine and other Quaternary deposits are constituted mainly from local material.

The above mentioned deposits gave rise to near neutral soils that contain almost all the vital macro- and microbiogenic elements. The soils in the Zaonezhye Peninsula, for example, are rich in mobile Mn, Zn, Cu and Mo as well as having the highest percentages of Co, B and Se anywhere in Karelia (Trace elements in Karelia, 1973; Chazhengina et al., 1985 and others). Some Zaonezhye rocks and soils are rich in V and Cr while others have high percentages of U and some rare elements. Some elements often occur in concentrations that exceed the HAC (highest allowable concentration) for agricultural soils. However, no physiological or morphological changes attributable to the high concentrations of chemical elements have been observed.

The ***Belomorian fold belt*** is dominated by biotite, amphibole-bearing and aluminous gneisses with up to 200 metre thick interbeds of amphibolite. The gneisses are similar in composition to those of the Karelian craton and the soils that rest on them are lacking in almost all the biogenic elements. Richer soils are formed on amphibolite and on small massifs made up of gabbronorite and other mafic magmatic rocks that generally cover small areas (mafic rocks are magmatic rocks which contain about 50% of SiO2). Small-scale rare element anomalies are occasionally encountered around pegmatite veins. The dependence of soil composition on bedrock is still poorly understood and no botanical studies have been carried out.

The western White Sea region consists of a gently undulating plain. Weathering and soil formation processes are slow here owing to the cooling effect of the White Sea. Furthermore, moraine has been repeatedly outwashed during the evolution of the glacial lake and the White Sea during and after glacial retreat. Between the towns of Kemi and Louhi coastal terraces of rounded boulders are common in upland locations of up to 137 metres above sea level. These are especially distinctive on sites of large-scale forest fires.

Rocky forest-tundra usually forms a 50 to 150/200 metre wide strip in the open coastal zone. *Arctous alpina* and various other typical tundra plants are encountered. Coastal forest usually consists of a narrow tundra forest zone formed by low flag-shaped trees with branches growing in the direction of the prevailing onshore wind. Bedrock exposures covered only by mosses and lichens are abundant in the shore zone. Trees grow only in narrow depressions along fault zones which typically vary from one or two kilometres to tens of kilometres in length, have a width of between 15 and 200 metres and occur as depressions 15/20 to 75/100 metres in depth. Hard crystalline rocks are highly fractured in fault zones and are altered to tectonic breccia in the central parts of the zones. Joints are often filled with low temperature minerals such as quartz, iron hydroxides, epidote, chlorite and calcite, etc. There are numerous springs of poorly mineralised groundwater which circulates in fault zones. In spite of the low concentrations of nutrient forming mineral matter some more demanding plant species grow well there.

Deep depressions in large dislocation zones are often protected against cold winds and have microclimates of their own. Trees growing in such valleys warmed by the sun along the Karelian White Sea coast near the Keret Archipelago reach heights of over 30 metres high whereas those in the coastal zone are typically 8–15 metres in stature. Also conducive to plant growth are the long light summer nights and the presence of the sea which accumulates heat during the summer. Thus, the monks of the Solovets Monastery were able to grow a variety of crops, vegetables and even apples.

The ***Svecofennian fold terrane*** is formed of heterogeneous, unequally metamorphosed Early Proterozoic sedimentary and volcanic rocks which appear in crops along the western and northern shores of Lake Ladoga. They are geochemically similar to the Early Proterozoic flded cover of the Karelian craton. Near the village of Ruskeala, where marble has been mined for over 250 years, carbonate rocks cover a large area. The geochemical characteristics of volcanic and sedimentary rocks contribute to the species diversity of the local flora.

Owing to the rugged relief of the region with its southward sloping hills protecting the Lake Ladoga basin against cold winds, many plants grow well here. The northern shores of Lake Ladoga and the Onega synclinore possess the greatest number of vascular plant species (more than 800) in the region.

The ***Platform Cover*** occupies a small area at the southeastern end of the region and is composed of Vendian-Paleozoic sandstone, limestone, marl and clay, as well as other sedimentary rocks not subject to metamorphism. This so-called platform is almost perfectly level, its inclination towards the south-southeast being only about three metres per kilometre. The sediments present are not as strong as Early Proterozoic sediment. At the boundary between the Fennoscandian shield and the Platform Cover the geochemical environment changes dramatically. Occurring among Devonian and Carboniferous sediments are large quantities of limestone and marl enriched in Mg, Ca and trace elements. The vegetation becomes noticeably more lush and species diversity increases markedly. This appears to offer an explanation as to why the number of vascular plant species is much greater in Kenozero National Park (about 700) than in Vodlozero National Park (about 420).

Thus, the composition of bedrock and presence of all necessary biogenic elements are of crucial importance for biodiversity.

Other geologic characteristics affecting biodiversity. The physical-mechanical properties of rocks, the orientation of geological structures and a network of faults in the Earth's crust all affect the formation of relief and the orientation of landforms. Thus, for example, faults in bedrock contribute to groundwater circulation, the composition and drainage properties of Quaternary deposits are related to the diversity of mire communities, and the colour of bedrock and soils is important for accumulating solar heat. All these features are determined according to the geological peculiarities of the area.

Relief and orientation of landforms. Karelia is located in North Europe between 61° N and the Arctic Circle and displays a gentle hilly relief resulting largely from ancient Precambrian geological processes. Large water bodies such as Lake Ladoga, Lake Onega and the White Sea are situated close to the Precambrian Fennoscandian shield margin. The altitudes of adjacent territories lie between a few metres and tens of metres above sea level. The greatest altitudes are reported from the northwestern part of the region, i.e. from Paanajärvi National Park and Maanselka Ridge, where 1) the central portion of the Fennoscandian shield is sharply uplifted and 2) intrusive magma rocks are of great mechanical strength. Nuorunen Hill (576 metres above sea level) and Mäntytunturi Hill (550 metres) are built of granite while the hills of Kivakka (499 m) and Pyainur (486 m) comprise large layered peridotite-gabbronorite massifs.

In the West Karelian Upland only some hills and ridges exceed a height of 400 metres while the highest point of the Olonets Upland reaches 313 metres. However, in the north even such small differences in altitude have a marked effect on microclimate. Frosts occur much earlier at elevated locations than on the shores of Lake Onega. Altitude is also important for aboriginal vegetation. Thus, southern species inhabit south-facing slopes and deep valleys whereas northern species persist under favourable conditions on cold north-facing slopes and in shady valleys. The most revealing example of this is the Lake Paanajärvi area where the east-west oriented lake basin cuts almost 500 metres into the surrounding rock. Protected against northerly winds, air temperatures in the valley of –50–55° C are not uncommon during the winter season. In summertime the dark steep rocky cliffs enclosing the valley create a type of greenhouse effect causing air temperatures several degrees higher than on the surrounding uplands. Lily of the valley (*Convallaria majalis*), nectarberry (*Rubus arcticus*) and other southern plants grow and bear fruit there. However, at an altitude of 450 metres above sea level where the treeless rocky mountain-tundra zone begins typical tundra plants such as *Phyllodoce caerulea* (L)*, Loiseleuria procumbens* (L)*,* and *Diphasiastrum alpinum* (L) occur.

The orientation of landforms is important for the formation of various microclimatic conditions and, consequently, for biodiversity. Most of the large folded and ruptured structures extend towards the northwest. Cases of east-west orientation have only been recorded at the central part of the western shores of the White Sea and at Paanajärvi-Kuukaisjärvi zone while north-south oriented structures are most commonly encountered in southern Karelia. Fault scarps occur on uplands and on the shores of large water bodies. Often consisting of a number of steps, some of these may be up to ten and more kilometres in length and a hundred metres in height.

Northern and northeastern slopes are exposed to northerly winds but also receive less warmth from the sun. Because the climate is always wet and cool here the slopes are typically inhabited by mosses, lichens and northern vascular plant species which are not found on southern and southwestern slopes and scarps. Microclimates are most severe in deep, narrow faults and valleys where snow does not disappear completely until mid-summer. Springs with water temperatures as low as +3.5–4° C occur in many places. Northern lichens growing in such valleys have only been found in the Kostomuksha Reserve and mosses on the northern shores of Lake Ladoga.

Warm south-facing slopes, especially south-facing scarps, have an altogether different microclimate even in northernmost parts of Karelia. Exposed to the sun and protected against winds, the sixty metre high Ruskeakallio cliff overlooking the northern shore of Lake Paanajärvi is heated to +35° C and consequently only a few drought- and heat-resistant species such as *Gypsophila fastigiata, Draba cinerea,* and *Asplenium ruta-muraria* can survive there. According to V. B. Zimin some southern bird species have found good nesting sites on the south-facing slope of Kivakka Hill.

Fault zones as conduits for groundwater. Fault zones are important both as relief-forming factors and as areas of strongly fissured rocks mineralised by low-temperature hydrothermal minerals such as quartz, carbonates, iron hydroxide, epidote, chlorite and others. Due to glacial erosion the rocks occurring in the central part of Precambrian crystalline blocks are fresh and of very low porosity. Processes of jointing and weathering occurred more intensively in fault zones and led to an induced porosity of the rock.. Thus areas occur with hydraulic conductivities ten to a thousand times greater than that of adjacent rocks. This causes a greater infiltration of atmospheric precipitation into the bedrock and allows the formation of conduits for water movement along the faults. Springs usually discharge near to fault scarps or on slopes. Groundwater dissolves and carries away a number of mineral nutrients required by plants. Even granite rocks occurring along fault zones support a richer vegetation than do non-fissured outcrops. A wide diversity of rare plant species characterise small mires located close to springs. This is especially the case if the surrounded bedrock contains sufficiently carbonaceous material. Commonly ten or more rare species may be found at such locations. Most large mires in the region also derive some of their water from groundwater sources discharging along fault zones in the bed of the mire. The territory of Karelia is covered by a thick network of fault zones (Systra, 1991).

Migration corridors. Only one effective and well-developed migration corridor is known within the region. This is the 75 km long River Olanga – Lake Paanajärvi – River Oulankajoki valley. (Hautala, Rautiainen, 1998). This river system cuts across the Maanselka Ridge, the highest points of which rise up to 400–600 metres above sea level. The system begins at just over 200 metres above sea level on the western side of ridge. From here it, nevertheless, flows eastwards via Lake Paanajärvi (136 metres) into Lake Pääjärvi (Kuma Reservoir, 109 metres) which discharges into the White Sea near the town of Kandalaksha. There are major differences between the plant, bird and animal populations of the Atlantic western and Arctic eastern slopes of Maanselkä. Significantly, over the last years certain new species of birds and plants have been found on both sides.

Colour of the bedrock. Shungite-bearing soils on the Zaonezhje Peninsula are black in colour and therefore warm up more quickly than do the light coloured sandy soils found elsewhere in Karelia. Many types of rock such as gabbro, diabase, amphibolites, slates and schists are dark in colour and this influences the microclimatic conditions of a number of locations near lakes Ladoga, Onega, Paanajärvi and Segozero, as well as on the southern slopes of numerous hills.

Conclusion. The great geological diversity of Precambrian rock, their physical-mechanical properties, mineral and chemical compositions, the availability of important nutrients in bedrock and soils, hilly relief and the absence of large water bodies together constitute an advantageous geological environment for the development of biodiversity in Eastern Fennoscandia. More detailed study of bedrock-soil-plant-animal systems is required in the future. Many uncharted sites possessing favourable geochemical environments may yet reveal new habitats of rare species and a rich biodiversity.

1.3. Geomorphological characteristics

Introduction. The geological and geomorphological structure of the region has contributed greatly to the formation and Late Pleistocene and Holocene evolution of its present-day landscapes. Unlike the extensive Russian plain rimming it on the east, southeast and southwest, Karelia has a structural pattern all of its own which owes itself to 1) the exposure of ancient crystalline rocks, 2) the predominance of uplands, 3) a specific type of neotectonic movement along rejuvenated old faults responsible for the block structure of the relief, 4) repeated glaciation during the Quaternary period and 5) the transgressive-regressive evolution of water bodies during the postglacial period.

Thus the present-day relief of Karelia has formed as a combination, on the one hand, of preglacial denudation-tectonic landforms and, on the other, of glacial, postglacial erosional and accumulative landforms. The first type of relief arose from the selective denudation of old crystalline rocks and a shift in altitude of individual rock blocks caused by neotectonic movement. The second type resulted from the geological activity of ancient ice sheets, glacial meltwater, and periglacial lake and sea basins (Fig. 4). The Quaternary deposits which rest on crystalline rocks are dominated by various types of glacial, glacifluvial, lacustrineglacial and lacustrine sediments (for more details see the section entitled ‘Quaternary deposits’). Various genetic types of relief occur in Karelia in complex combinations and the Quaternary cover is structurally heterogeneous.

The formation and evolution of landscapes is profoundly affected by the layering of relief, the horizontal and vertical ruggedness of the terrain, the prevalence of one or other type of landform, and the thickness, lithological composition and type of Quaternary sequence.

The occurrence of neotectonic highs varied in intensity from one part of Karelia to another. As a result three regional denudation steps, or storeys, were formed in its relief, the peak plains of their watersheds differing markedly in altitude. These consisted of an upper storey with an average altitude of watershed surfaces at 250–350 metres above sea level, a middle storey with altitudes of 140–160 metres and a lower storey at 100–120 metres. An important factor in the evolution of natural landscapes is the horizontal and vertical ruggedness of the surface. Horizontal ruggedness indicates the extent of drainage. The extent of horizontal ruggedness is given by what is known as the ruggedness index. Values in Karelia vary from 0.128 to 0.270 and may be divided up into three categories: high (0.220–0.270), moderate (0.151–0.168) and low (0.128–0.130). Vertical ruggedness indicates the depth with which streams cut into the surface of the terrain as well as the relative height and occurrence of slopes. Vertical ruggedness indices for Karelia vary from between 20 and 250 metres and may also be subdivided into three categories: high (100–250 metres), moderate (60–90 metres) and low (20–50 metres).

The most common genetic types of relief are 1) denudation-tectonic, 2) glacial accumulative (morainic plains) and 3) abrasion-accumulation aqueoglacial (lacustrineglacial, marine and lacustrine plains). Linear accumulation complexes are represented by end morainic ridges and radial glacifluvial ridges. The former are associated with interlobate accumulative elevations indicating the boundaries of ice lobes at different glacial stages while the latter take the form of eskers, often in association with deltas. The landforms of the region differ morphologically. According to their outlines in plan view, denudation-tectonic landforms may be categorised as isometric (blocky and hilly) or linear (ridge complexes). They may also be classified as large, medium or small. Some areas within morainic plains have undulating or hilly surfaces while others contain drumlin fields with linear ridges.

Some genetic types of relief occur in combinations. As a rule one type dominates over a large area with other types occurring less frequently. The upper storey of the earth surface is dominated by denudation-tectonic landforms while morainic plains and eskers are less common. In the middle storey morainic plains prevail and denudation-tectonic landforms appear less often. In the lower storey aqueoglacial abrasion and accumulation plains are widespread.

Both the layering and ruggedness of the relief have a strong bearing on the lithological composition, character and thickness of the unconsolidated cover. In the upper storeys and in areas with highly rugged surfaces the sedimentary cover is thin and broken at locations where denudation-tectonic scarps occur on accumulation plains. In the middle and especially lower storeys the cover is predominantly continuous.

The thickness of the Quaternary deposits varies from 2–3 to 60–120 metres and is divided into 1) thin (1–10 metres), 2) medium (10–30 metres) and thick (40–120 metres). The Quaternary cover varies not only in thickness but also in sequence structure. Depending on the number of lithological types of discontinuous rocks, sequences fall into three groups which reflect the geological and lithological heterogeneity of the cover: I) monogenetic, II) bigenetic and III) polygenetic (Barkanov, 1967; Lukashov, 1976; Trofimov & Fadeyev, 1982). There is only one lithological type of rock in a monogenetic sequence while bi- and polygenetic sequences contain two or more interlayering rock types respectively. The thickness of a sequence usually depends on its type. The thickness of the cover and the predominant type of sequence involved are of great importance for the evolution of soil cover and the extent of moistening and paludification of an area. Based on all these factors Karelia may be geomorphologically classified and subdivided into provinces and subprovinces.

Geomorphological provinces are distinguished according to the layering of relief, the degree of surface ruggedness and the dominance or secondary dominance of one or other type of relief. Subprovinces are distinguished on the basis of differences in surface ruggedness, in the morphology of denudation-tectonic and accumulative landforms, the continuity of the unconsolidated cover, variations in the thickness of sediments and the prevalent type of sequence.

Geomorphological classification. In terms of geomorphological structure Karelia may be divided up into five geomorphological provinces (GP): 1) North Karelia, 2) Central Karelia, 3) White Sea Province, 4) West Karelia and 5) South Karelia. Each, in turn, falls into a number of subprovinces (Fig. 5), the main geomorphological characteristics of which are shown in Table 1.

The topographic pattern of the provinces is as follows:

1. The **North Karelian GP** lies in northwestern Karelia and covers the most uplifted area of Karelia (upper storey of relief). Average absolute altitudes of watershed areas vary from 190 to 350 metres above sea level. The highest individual massifs include Nuorunen (576 m), Lunas (497 m), Pyainur (488 m) and Kivakka (500 m), (Biske, 1959). Since in terms of peak plain altitude they resemble low mountain areas they also exhibit vertically zoned vegetation. The surface of the province is slightly rugged horizontally and highly rugged vertically. Denudation-tectonic landforms are extensive while fragments of undulating morainic plains are less common. The Quaternary cover is discontinuous and varies in thickness from 0.5 to 6 metres. The province is morphologically subdivided into two subprovinces: 1a) Lunas and 1b) Pistojärvi. These differ slightly in terms of the altitude of watersheds, extent of vertical ruggedness and succession of large ridge-block relief by a block-ridge landform.

2. The **Central Karelian GP** is located in the centre of the region and consists of middle storey relief. It has a relatively level surface with low degrees of horizontal and vertical ruggedness. This province is characterised by a relatively large number of large lake basins (Topozero, Pyaozero, Ondozero, Segozero, Vygozero, etc.). Morainic plains make up the predominant landform. The province falls into two morphological subprovinces: 2a) Shombozero and 2b) Ondozero. Absolute altitudes of watersheds decline from subprovince 2a towards subprovince 2b with drumlin fields on morainic plains giving way to hilly terrain and the sedimentary cover becoming more continuous.

3. The **White Sea GP** is restricted to the Karelian and Pomor White Sea coasts. It is a paludified coastal lowland with lacustrineglacial and marine accumulation plains. Lower storey relief is widespread, its surface being highly rugged horizontally and slightly rugged vertically. The province falls into three subprovinces displaying widely differing characteristics: 3a) Engozero, 3b) River Kuzema and 3c) Kolezhma.

The Engozero subprovince is the most uplifted and rugged part of the coastal lowland, maximum altitudes of watersheds lying at 40–110 metres above sea level. Horizontal ruggedness is high and vertical ruggedness low (15–30 m). Small to medium-sized denudation-tectonic ridges are the predominant landform, fragments of submarine plain in lows between ridges being less common. The 0–6 metre thick layer of sedimentary cover is mainly discontinuous and displays the Type I sequence.

The relief of the other two subprovinces is flatter with lacustrineglacial and marine accumulation plains prevalent. The sedimentary cover is more continuous, its thickness ranging from 5–10 to 20–30 metres.

4. The **West Karelian GP** is the most complex orographic province in Karelia. It consists of three ranges of large ridges which together form the West Karelian Upland. The province is restricted to the upper topographic storey although absolute watershed altitudes and incision depths vary from area to area. The province falls into three subprovinces: 4a) Tikshozero, 4b) Maslozero, and 4c) Koitajoki.

The Tikshozero subprovince is located in the northern part of the West Karelian province. Its watersheds lie at altitudes of 160–280 metres above sea level and are moderately rugged. A large-scale block-ridge denudation-tectonic landform predominates. Morainic plains with drumlin fields and eskers occur less frequently. The subprovince also contains two belts of end-morainic ridges formed during the Rugozero and Kalevala glaciation stages. The 1–6 metre thick sedimentary cover is discontinuous and is of Type I sequence.

The Maslozero subprovince is the most orographically conspicuous part of the West Karelian Upland. It contains three systems of ridges with the highest watershed altitudes of Western Karelia (220–345 metres) as well as a

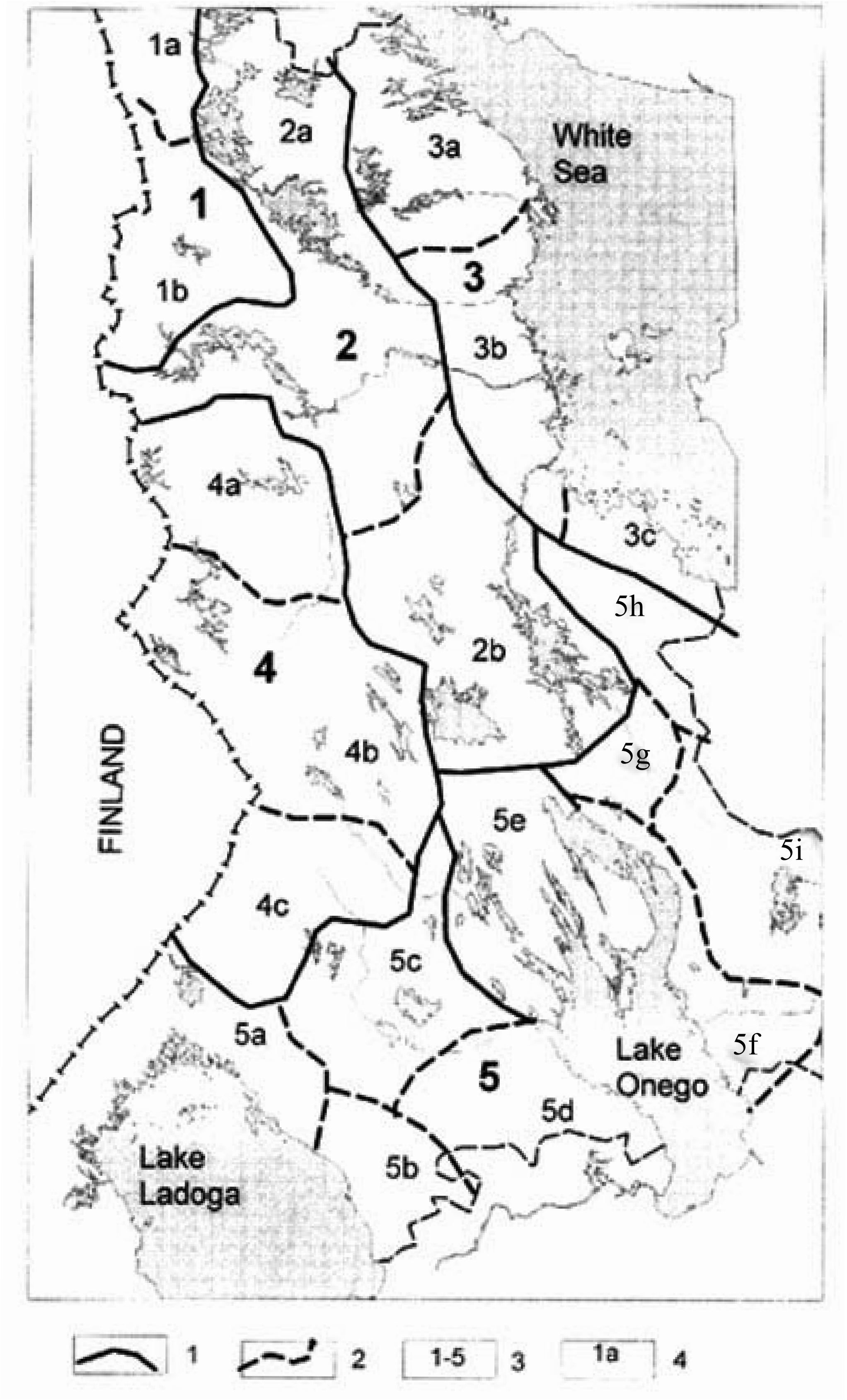

Fig. 5. Geomorphological scheme of Karelia

1 = boundaries of provinces; 2 = boundaries of subprovinces; 3 = numbers of provinces; 4 = numbers of subprovinces.

Table 1

Major characteristics of geomorphological provinces

Provinces and subprovinces	Storey (Upper/Middle/ Lower) and absolute altitudes of watersheds	Horizontal ruggedness of surface	Vertical ruggedness of surface and incision depth	Dominant type of relief	Associated type of relief	Extent of continuity of sedimentary cover and dominant thickness	Type of sequence of unconsolidated deposits
Province 1 North Karelia	Upper 200–350 m	Low	High	Denudation-tectonic	Undulating morainic plain	Largely discontinuous cover	
1a. Lunas	350 m	0,130	130–250 m	Large ridge-block		0,5–6 m	I
1b. Pistojärvi	200 m	0,130 m	70–190 m	Large block-ridge		0,5–6 m	I
Province 2 Central Karelia	Middle 112–160 m	Moderate	Low	Glacial	Small to medium-scale hilly		
2a. Shombozero	112–160 m	0,160	18–48m	Morainic plain with drumlins	Small ridge-hilly	Discontinuous cover 1–10 m	I
2b. Ondozero	136–160 m	0,160	Low 20–51 m	Hilly plain morainic	Medium-scale ridge	Predominantly continuous 1–8 m	I and II
3. White Sea province	Lower 23–110 m	High		Aqueoglacial and marine plains	Small ridge-hilly		
3a. Engozero	40–110 m	0,220	Low 15–30 m	Denudation-tecto-nic and medium-scale to small ridge	Lacustrineglacial and marine plains	Predominantly discontinuous 0–6 m	I
3b. River Kuzema	70–110 m	0,220	Low 11–18 m	Lacustrineglacial and marine plains	Individual denudation-tectonic ridges and hills in coastal zone	Predominantly continuous 5–10 m	I and II
3c. River Kolezhma	23–40 m	Low 0,126	Low 9–18 m	Marine accumulative plain	Fluvioglacial massifs	Continuous 20–30 m	II
Province 4 West Karelia	Upper 170–345 m	Moderate	Variable	Denudation-tectonic	Morainic plain	Predominantly discontinuous	
4a. Tikshozero	160–282 m	0,160	Moderate 0–70 m	Large ridge-block	Morainic plain with drumlins and eskers	Discontinuous 1–6 m	I
4b. Maslozero	220–345 m	0,160	High 80–235 m	Large-ridge	Morainic plain with drumlins	Discontinuous 1–6 m	I
4c. Koitajoki	170–182 m	0,160	Low 30–60 m	Hilly morainic plain with drumlins and eskers	Medium-scale ridge, small ridge-hilly	Locally discontinuous 3–6 m	I and II
Province 5 South Karelia	Lower, locally middle	Moderate	Varies from area to area	Varies from one subprovince to another	Varies from one subprovince to another	Variably continuous	
5a. Priladozhye	Lower 60–100 m	High 0,245	Moderate 30–75 m	Medium-scale ridge and ridge-hilly	Undulating morainic plain with marginal ridges and aqueoglacial plain	Discontinuous 1–5 m	I and II
5b. Olonets	Lower 26–41 m	Moderate 0,157	Low 10–17 m	Lacustrineglacial and lacustrine plains	Eskers and end morainic ridges	Continuous 20–40 m	I and II
5c. Syamozero	Lower 108–138 m	Moderate 0,157	Low 19–57 m	Interlobate accumulation uplands and lacustrineglacial plains	Hilly morainic plain, eskers	Continuous 20–40 m	I, II and III
5d. Mashozero	Upper 120–180 m	Moderate 0,157	Moderate 45–75 m	Hilly morainic plain with ice terminal formations	Medium-scale ridge relief	Predominantly continuous	I
5e. Zaonezhye	Lower 60–107 m	High 0,270	Low 26–38 m	Medium-scale ridge	Morainic plain with eskers and lacustrineglacial plains	Locally discontinuous 1–5 m	I and II
5f. Shala	Lower 42–80 m	Low 0,128	Low 12–25 m	Lacustrineglacial and lacustrine plain	Hilly morainic plain with end moraines	Continuous 10–60 m	I, II and III
5g. River Vyg	Lower 135–160 m	Moderate 0,160	Low 25–60 m	Hilly morainic plain with interlobate accumulation uplands	Medium-scale to small ridge relief	Predominantly continuous 1–8 m	I and II
5h. Windy Belt	Middle 117–145 m	High 0,200	Moderate 40–65 m	Large ridge	Morainic plain with terminal glacial formation	Locally discontinuous 5–10 m	I, II and III
5i. Vodlozero	Lower 140–160 m	Low 0–130	High 60–80m	Hilly morainic plain	Interlobate accumulation upland, marginal morainic ridges and eskers	Continuous 20–60 m	I, II and III

high degree of vertical ruggedness (80–235 metres). Large ridges are the predominant landform while morainic plains with drumlin fields are more scarce. The 1–6 metre thick sedimentary cover is discontinuons and displays only the Type I sequence.

The flattest part of the province is Koitajoki. This subprovince is dominated by morainic plains with drumlin zones and esker ridges. Its 3–6 metre thick sedimentary cover is continuous. Both Type I and Type II sequences are found here.

5. The **South Karelian GP**. In geomorphological terms this is the most complex province in Karelia due to the presence of Ladoga and Onega, the two largest lake basins in the region, together with the markedly elevated Ladoga-Onega and Onega-White Sea watersheds. The accumulation landform present includes almost all the major genetic types known in Karelia. In addition to lacustrineglacial and morainic plains the province has belts of end morainic ridges, large interlobate accumulative elevations and esker-deltaic complexes. Interlobate elevations associated with terminal glacial formations are characteristic (Fig. 1) and occur as uplifted massifs with relative altitudes of up to 120 metres. The largest elevation at Sumozero covers an area of 3750 km^2. These elevations display a complex relief and are composed of some 80–100 metres of glacial and glacifluvial deposits (Lukashov & Ekman, 1980). On the basis of geomorphological characteristics the province may subdivided into nine subprovinces: 5a) Priladozhye; 5b) Olonets; 5c) Syamozero; 5d) Mashozero; 5e) Zaonezhye; 5f) Shala; 5g) River Vyg; 5h) Windy Belt; and 5i) Vodlozero.

5a. Priladozhye. This subprovince falls into three zones. To the north of the lake basin is an area dominated by block-ridge denudation-tectonic relief. The watersheds here lie at 60–120 metres above sea level and are the highest within the subprovince. The surface of this zone is highly rugged horizontally and moderately rugged vertically (60–80 metres). In western Priladozhye, close to the state border, lies a large complex of end morainic ridges and glacifluvial deltas which formed during the Salpausselka stage I and have relative altitudes of 30–40 metres. The northern end of the Ladoga lake basin is characterised by a skerry and fjord type coastline. Fragments of lacustrineglacial and morainic plains make up an associated relief. The 1–6 metre thick sedimentary cover is largely discontinuous and is formed from both Type I and Type II sequences.

The **subprovinces 5b Olonets** and **5f Shala** have much in common. They cover an area of lowland close to the lakes Ladoga and Onega and containing extensive lacustrineglacial and lacustrine accumulation plains.

5c. Syamozero. This subprovince contains a variety of interlobate accumulative elevations and is restricted to lower storey relief. Its surface is moderately rugged horizontally and only slightly rugged vertically. The 20–40 metre thick sedimentary cover is continuous. All three types of sequence occur here.

5d. Mashozero is a large elevated subprovince embracing the Olonets Upland. The upland peak plane comprises upper storey relief (120–180 metres above sea level). Moderate horizontal and vertical ruggedness is characteristic. The predominant landform is a hilly morainic plain with a belt of terminal morainic ridges. Denudation-tectonic ridges are less common. The 3–10 metre thick Quaternary cover is mainly continuous.

5e. Zaonezhye encompasses the Zaonezhye Peninsula in Lake Onega and the zones that adjoin it on the western side. It comprises lower storey relief with peak plain altitudes of 60–107 metres above sea level. The surface is highly rugged horizontally but only slightly rugged vertically. A clearly ridge denudation-tectonic (selga) landform predominates. This takes the form of alternating long, narrow, steeply sloped ridges and the linear depressions which separate them. These depressions are filled with water from the bays of Lake Onega and from other lakes. Hilly morainic plain with esker ridges and glacifluvial deltas as well as lacustrineglacial and lacustrine accumulation plains all occur to a lesser degree. The 1–5 metre thick sedimentary cover is discontinuous.

5g. The River Vyg subprovince lies to the south of Lake Vygozero in the lower storey of relief . Its watersheds lie at 135–160 metres while vertical ruggedness is 25–60 metres. The predominant landforms are hilly morainic plains and interlobate accumulative elevations. Small to medium-sized denudation-tectonic ridges occur to a lesser extent. The 1–8 metre thick sedimentary cover is mainly continuous.

5h. The Windy Belt forms a range of low forest-covered hills with peak plain altitudes of 117–145 metres above sea level (these are high values for this part of Karelia) which therefore correspond to middle storey relief. The surface is highly rugged horizontally (0–200 metres) and moderately rugged vertically (40–65 metres). A morainic plain with an interlobate accumulation upland and marginal morainic ridges makes up the predominant landform. The 5–10 metre thick sedimentary cover is locally discontunuous.

5i. Vodlozero is from a morphological point of view quite remarkable. It consists of a hilly plain with a relatively high degree of vertical ruggedness. Interlobate accumulative elevations, hilly morainic plains and marginal units are common. The sedimentary cover is continuous and has a thickness of up to 60 metres.

The geomorphological environments of Russian Karelia and Finland: a comparative assessment. A number of similarities and differences between the geomorphological environments of Karelia and Finland have been identified. A large part of Finland lies in the upper storey of relief with absolute watershed altitudes estimated at 325–762 metres above sea level. Vertical ruggedness in Finland is higher (95–155 metres) than the average for Karelia. Middle and lower storey relief is restricted to the coastal zones of the Gulf of Bothnia and the Gulf of Finland. However, unlike Karelia, widespread lacustrineglacial and marine plains do not occur in the lower storey. Aqueoglacial accumulation and morainic plains alternate with denudation-tectonic landforms.

The major genetic types of denudation-tectonic and accumulation relief of the two countries are similar with the following exceptions. Denudation-tectonic landforms with almost no quaternary cover are more common and extensive in Finland than in Karelia. Similarly, esker ridges are longer and more common in Finland. Indeed, of the 20 000 km of eskers in the two countries some 70% of these lie in Finland. Drumlin fields on morainic plains are larger in Karelia. Finland has no Late Pleistocene ice-marginal zones with characteristic large and high interlobate elevations. Furthermore, the sedimentary cover in Finland is thinner and less continuous over large areas.

One of the most important geomorphological provinces in Finland is Greater Saimaa. This is a complex system of numerous lakes which covers a huge area. Its surface is highly rugged both horizontally and vertically, and displays a complex combination of denudation-tectonic, glacifluvial and glacial accumulation landforms and end-morainic ridges (Niemela at al., 1993).

Comparison of geomorphological provinces with the spatial distribution patterns of principal types of landscapes (Gromtsev, 2000) shows that provinces with relatively uniform geomorphological characteristics contain simple landscape environments. Correspondingly, the more contrasting the combinations of various geomorphological characteristics the more diverse the types of landscapes occurring.

1.4. Quaternary deposits

Introduction. The biodiversity of an area depends on its climatic, geological and geomorphological conditions and their Quaternary evolution. During the Pleistocene epoch global climatic changes repeatedly triggered large scale glaciations which transformed the earth surface, relief, surface deposits, lakes and rivers. During the late glacial period plant and animal communities reinvaded land freshly exposed in the wake of the retreating ice. The distribution pattern of these communities was largely dependent not only on palaeoclimatic but also on geologic and geomorphological conditions affecting moisture and heat supply, soil formation patterns, the composition of underground and surface water as well as the hydrography. Biota was most diverse at climatic optima during interglacial periods when the level of the global ocean rose and sea water flooded the edges of continents.

Thus, global climatic changes triggered global geological processes such as ice sheet formation and marine transgressions which shifted climatic belts and vegetation zones on the planet. Entirely new plant and animal species, e.g. the so-called mammoth fauna, emerged and vanished. Drastic changes in drainage systems gave rise to long distance migration and mixing of fish fauna.

At regional and local levels smaller scale climatic changes which occurred during glacial and interglacial periods also had a considerable effect on the formation and evolution of landscapes and biodiversity.

Karelia is a model province in terms of the effects of major continental glaciation. Various types of glacial and glacifluvial deposits together with the landforms built up from them are well preserved here. They provide the basis for the formation of modern landscapes. The stadial degradation of the last Scandinavian ice sheet and associated large periglacial water bodies, such as the Baltic Sea, the White Sea and Lake Onega, is reflected in the compositionally and structurally differing lithomorphological complexes of glacial and glacifluvial deposits that we find today. Multiple climatic changes gave rise to the present biodiversity of the region.

Structural characteristics of the Quaternary cover. The structure of the Quaternary cover of Karelia has been described by many authors (Biske, 1959; Ekman & Iljin, 1995; Niemela et al., 1993). Therefore, let us here briefly discuss only its major features.

The Quaternary cover is dominated by the glacial and glacifluvial deposits that formed mainly on Precambrian bedrock during the last Late Valdayan (Weichselian) glaciation. They are locally overlain by younger lacustrine, marine, alluvial and aeolian sand-clay material and peat deposits. The average thickness of Quaternary cover in Karelia is 7–12 metres. Some large territories, mainly areas of bedrock scarp or zones significantly affected by lake, sea or river erosion, have either 1–1.5 metre thick drift deposits or no drift at all. The Quaternary cover increases in thickness to 20–60 metre in active glacial (end moraines, ice-divide uplands) and glacifluvial (esker ridges, glacifluvial deltas and kames) accumulation zones. Lacustrine sand-clay sediments and peat deposits commonly vary in thickness from a few metres up to fifteen metres.

In southern and eastern Karelia drill holes penetrated Early, Middle and Upper Pleistocene glacial and glacifluvial deposits separated by marine and continental sand-clay material deposited during interglacial periods. At these locations the Quaternary cover has a total thickness of 120–150 metres.

Characteristic of surface deposits and the sequential landforms they compose is a fan-shaped form, very distinct in plan view, inherited from the last ice sheet. Extensive glacial depressions and long, narrow interlobated zones make up these radial mesoforms of relief. Concentric mesoforms are represented by five belts of varying age. Composed of end moraines these show the position of the retreating ice margin (Fig. 6).

The Quaternary cover of Karelia may be subdivided into a number of *principal lithomorphological complexes*. Differences in the composition of their constituents and relief are largely responsible for the diversity of ecosystems in the region. The formation of these complexes was profoundly affected by the palaeoglaciological pattern of degradation during the most recent glaciation and associated ice-dammed lakes. It was also influenced by an intricate interaction of climatic factors as well as the composition and relief of the glacier bed.

Glacial depressions occur as large morainic, often drumlinised plains which succeeded ice flows and lobes. They typically occupied large low-lying locations in the crystalline basement restricted to the present day Lake Onega, Lake Ladoga and White Sea basins. The thickness of the basal till that built up glacial depressions was affected by bedrock topography, ice accumulation patterns and the presence of unconsolidated Upper Valdai deposits on the

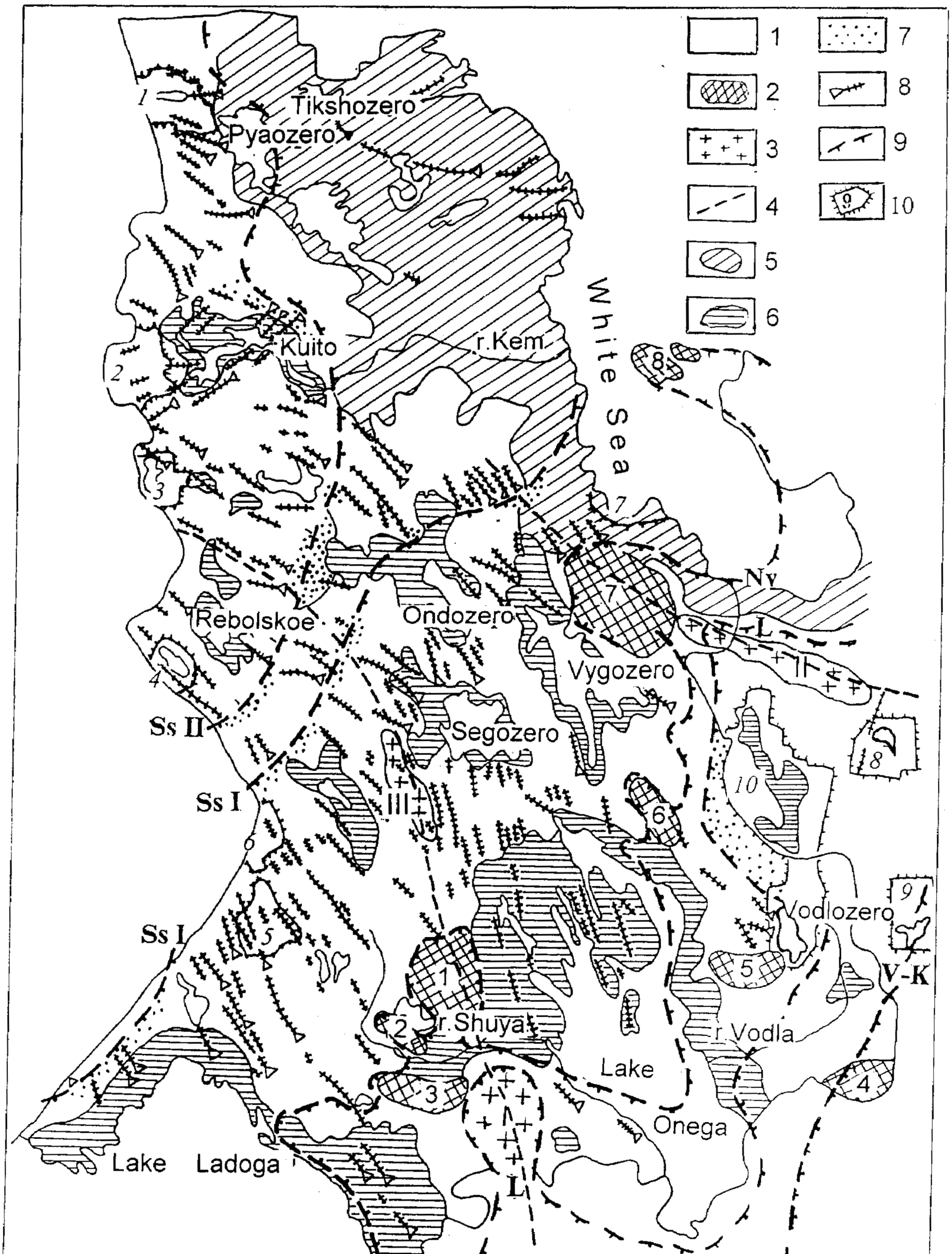

Fig. 6. Structure of the Quaternary cover in southeastern Fennoscandia (after I. Ekman, V. Iljin and A. Lukashov)

Symbols: 1 = morainic plains; 2 = ice-divide accumulative elevations and hilly moraines (1 = Vokhtozero, 2 = Veshkelitsa, 3 = Vodlozero-Urok, 4 = Andoma, 5 = Vodlozero, 6 = Volozero, 7 = Sumozero, 8 = Solovets); 3 = large bedrock uplands (I = Olonets, II = Windy Belt, III = Yangozero); 4 = major ice-divides; 5 = silt- and clay-dominated glacial-marine, marine and lacustrineglacial plains; 6 = lacustrineglacial and lacustrine plains predominantly composed of sand and silt; 7 = outwash sandy plains; 8 = eskers and glacifluvial deltas; 9 = ice-marginal positions (V-K = Vepsovian-Krestets stage, ~ 16 000 years ago; Lg = Luga stage, ~ 13–14 000 years ago; Nv = Neva stage, 11 800–12 5000 years ago; Ss I = Salpausselka I, 11 300–10 800 years ago; Ss II = Salpausselka II, 10 600–10 200 years ago); 10 = existing (NP) and proposed (PNP) national parks and landscape reserves (LR): 1 = Paanajärvi NP, 2 = Kalevala PNP, 3 = Kostomuksha Strict Reserve, 4 = Tuulos PNP, 5 = Tolvajärvi LR, 6 = Koitajoki PNP, 7 = Soroksky LR, 7 = Kozhozero LR, 9 = Kenozero NP, 10 = Vodlozero NP glacier bed. During the early stages of deglaciation the glacier slid over thick Quaternary and Palaeozoic sand-clay deposits in southern and southeastern Karelia. The glacier eroded and redeposited them as a 15–20 metre thick, boulder-poor till which covered the rugged preglacial land surface. In the final stages of glaciation continental ice advanced across erosion-resistant Precambrian granite and gneiss – an environment conducive to the formation of a 3–6 metre thick layer of sandy and gravel till. Here the till cover displays a mosaic pattern and is fragmented by numerous bedrock scarps. Drumlin ridges varying in length from tens of metres to several kilometres were generated by thin ice flows moving actively along the glacier bed. Till varies in thickness from three to five metres in between drumlins to at least 20 metres in large drumlins.

Morainic plains, especially interdrumlin lows, are usually paludified. Illuvial-humus and illuvial-ferruginous-humus soils combined with peat bog soils are common. Growing on them are pine and spruce-pine forests. In small lakes formed on the morainic plains atmospheric nutrition prevails and the water is poorly mineralised. Bottom sediments in small lakes are dominated by sapropel which occurs either as an organogenic type or as a mixture of the remains of aquatic organisms with traces of minerals. Rivers flowing through boulder-rich morainic plains have only low flood plains and rapids, their bottom deposits commonly consisting of coarse, clastic channel-alluvium facies.

The diverse rock and mineral content of till and other Quaternary deposits reflects the complex composition of the bedrock across which the ice moved. Thus, for example, in localities where carbonate rocks are common such as southeastern Karelia, the Paanajärvi area and some parts of the Yangozero structure, calcareous sapropel is deposited in small lakes. Relatively fertile sod-lithogenic soils are widespread on shungite and mafic rocks in the Zaonezhye Peninsula. Glacial depression landscapes formed by drumlinised morainic plains are very common. They were produced in the final phases of glacial waning when the ice moved across Precambrian crystalline rocks. In western Karelia such areas are found in the proposed Tuulos and Kalevala national parks and in the vicinity of the Kostomuksha Strict Reserve. Formed during the final stages of glaciation esker ridges, glacifluvial deltas and small periglacial water bodies are also characteristic.

Glacial depressions generated in the early stages of glacial retreat typically host large water bodies, such as lakes Ladoga and Onega, or are subdued by younger limnoglacial, lacustrine or mire sediments. Fragments of a gently sloping hilly morainic plain resting on a rugged preglacial bed occur in the northern (Arkhangelsk) part of Vodlozero National Park.

The structural characteristics of aqueoglacial deposits of widespread occurrence in glacial depressions are discussed below.

Ice-divide zones are formed by 1) large scale bedrock scarps which controlled the direction of ice flows and lobes in the final stages of deglaciation and 2) large accumulation ridges and elevations generated at points of contact between ice flows moving in different directions.

Large bedrock scarps have either a 1–3 metre thick Quaternary cover or no cover at all. They are predominantly overlain by thin local till containing considerable volumes of boulders and blocks of local rocks, and by eluvial-deluvial coarse rock debris produced by frost weathering. A most scenic example of this type of landscape may be found on top of Vottovaara, the highest mountain (417 metres above sea level) in the West Karelian Upland. Here deep glacial erosion generated thin localised layers of till formed by clusters of local quartzitic sandstone boulders and blocks measuring 3–4 metres. Sand particles were washed out and blown away during late and post-glacial periods while the disastrous earthquake which occurred some 9 000 years ago removed all sand-gravel particles from the till. These events gave rise to a unique landscape formed by seid-like clusters of boulders and blocks. In the northern part of Vodlozer National Park eluvial-deluvial coarse rock debris occurs in the branching Windy Belt range.

Structurally, **ice-divide accumulative elevations** are the most complex lithomorphological forms of glacial relief. They are formed from glacial deposits and sandy-clay sediments of aqueoglacial genesis. They vary in size from 150 km^2 (Veshkelitsa and Vodlozero uplands) to 2000 km^2 (Sumozero Upland). Their Quaternary deposits are at least 80 metres thick. Ice-divide accumulative elevations are characteristic of areas where the ice retreated during the early stages of the last glaciation. They are widespread along the periphery of the final ice sheet all the way from the Baltic Sea to the White Sea. This partly explains why an areal deglaciation pattern prevails in the early stages of glacial waning. At that time tremendous volumes of ice at the periphery of the glacier were breaking off from the retreating ice margin and took hundreds or even thousands of years to melt. At the same time, however, unconsolidated preglacial deposits in central and western Karelia were not large enough to lead to large scale landforms during the last glaciation.

During the final stages of glaciation a thin glacier advanced across Precambrian erosion resistant crystalline rocks. Radial ridges composed of approximately 20 metres thick till or fluvioglacial material formed at the points of contact of the inequidirectional ice lobes of the glacier.

Ice-divide accumulative elevations typically occur as a complex combination of hills and ridges differing in shape and height. They result from both the dynamic impact of the active glacier and the melting of blocks of ‘dead ice’. Many small water bodies were located in ice-divide elevations which became freed of ice during the Vepsovian (Andomian and Kenozero) and Luga (Vodlozero and Sumozero) stages. Lake sedimentation in these water bodies did not begin until the Early Holocene. The ice took four to five thousand years to melt during the late glacial time, a period of cold climate and developing permafrost. The resultant elevation relief is both vertically and horizontally rugged and consists of an alternation of hills and ridges composed of till and well drained sand-gravel deposits. The numerous lakes and swamps formed in topographic lows present unusual profiles. The mosaic pattern of relief causes differences in the moisture and heat supply between the different parts of uplands and consequently affects soil formation, paludification and the structure of the vegetative cover. A typical landscape of ice-divide accumulative elevations was produced by an alternation of ridges, ring eskers and morainic and sand hills in the southern Soroksky Landscape Reserve close to the southwestern coastline of the White Sea shore and in the Vodlozero Upland near the southern boundary of Vodlozer National Park.

Marginal glacial deposits. There are five belts of uneven age formed by ice-marginal deposits that mark the retreating glacier margin from the Vepsovian stage (~ 16 000 years ago in southeastern Karelia) to the cold final Salpausselka stage II (10 200years ago in western Karelia). The marginal formations produced during the early stages of glacial waning (Vepsovian-Krestets and Luga) are largely composed of kames, clayey kames (zvontsy) and hilly moraines generated by large scale ice melting. The marginal deposits formed during the Vepsovian-Krestets stage in southeastern Karelia and in adjacent parts of the Arkhangesk Oblast are up to 20 km wide and over 40 metres thick. The landscapes of this zone are fairly similar to the ice-divide uplands mentioned above and occur as an irregular alternation of sand and morainic hills and ridges which differ in both height and shape and are separated by lows occupied by lakes and swamps. A typical accumulation relief sculptured by the large scale melting of ice is to be found in Kenozero National Park and in the Kozhozero Landscape Reserve near the eastern border of Karelia.

The marginal formations constructed in the final (Salpausselka I and II) stages of glaciation are thinner. In western and central Karelia they occur as series of push end-morainic ridges that extend for hundreds of metres, reach up to 20 metres in height and vary in width from tens to hundreds of metres. Their distal parts are often adjoined by glacifluvial deltas and sandy outwash plains, their size and thickness depending on the bedrock relief which controlled the flow of meltwater from the ice margin.

Lacustrineglacial and glacial-marine plains. Large parts of glacial depressions are overlain by deposits formed in periglacial basins that existed near the ice margin. The largest of these were hosted by the present Lake Ladoga, Lake Onega and White Sea basins and by adjacent lowlands. The area and depth of the basins, together with the composition and areal distribution of their deposits, were determined by preglacial relief, the position of the ice margin, changes in runoff thresholds in the course of ice melting and glacio-isostatic crustal uplift.

Periglacial basin deposits are composed of homogeneous or varved clay which formed at depths of over 20 metres as well as arenaceous sediments that accumulated in the littoral zone of lakes. They are commonly three to seven metres thick but in some areas such as the lower River Kemi and the Kumsa reservoir their thickness increases to 20–25 metres. Periglacial water body sediments commonly cover glacial and bedrock relief and contribute to paludification. Bog humus and peat soils, combined with sod-podzol-gley soils, evolve on aqueoglacial clay and silt deposits. Growing on them are paludified birch-spruce and spruce-pine green-moss forests. Lacustrineglacial plains are most common along the White Sea, Onega and Ladoga lake shores and in the lower stretches of the Vodla and Shuya rivers. A landscape of swamps and paludified forests on an old lacustrineglacial plain characterises most of the River Ileksa basin in Vodlozer National Park.

In the highly rugged bedrock topography of northern Priladozye the granitic domes of the crystalline basement tower over the flat surface of lacustrineglacial plains. Rivers occurring on thick deposits of aqueoglacial sand-clay form well-developed valleys with two or three terraces above the flood plain. Further downstream they slow to form meanders and oxbow lakes. Typical examples are the Koitajoki and Luovenjoki river valleys in the proposed Koitajoki National Park, the Vodla river valley between the city of Pudozh and village of Krivtsy, and the lower stretches of the River Shuya close to its point of discharge into Lake Onega near Petrozavodsk.

Esker ridges are of widespread occurrence. They were mostly generated during the final stages of glaciation when the active glacier was sliding across tough crystalline Precambrian rocks. Rugged bedrock topography and vigorous ice melting during the warm Allerod period and the Pre-Boreal period contributed to the predominance of a linear pattern of glacifluvial accumulation. Forming in tunnels under the ice and in ice cracks were vigorous meltwater flows which gave rise to systems of esker ridges commonly combined with glacifluvial terraces and deltas. These esker ridges are several kilometres in length and vary in height from 20 to 60 metres. Groups of eskers typically form large scale glacial meltwater discharge systems (e.g. the Uksa, Boyarskaya and Yangozero systems) that extend for hundreds of kilometres. Karelia has over four hundred esker ridges with a total length of about 6 400 km. 75% of these ridges were formed in Allerod time, the warmest interstadial in the late glacial period. Kame fields, clayey kames (zvontsy) and large lacustrineglacial basins were the dominant landforms produced in earlier stages of deglaciation in southeastern Karelia. This suggests that an areal rather than linear character of aqueoglacial accumulation prevailed. The total length of esker ridges in southeastern Karelia accounts for only ten percent of all ridges in Karelian eskers.

The thickest and most typical esker ridge systems occur in the Tolvajärvi Landscape Reserve. In Paanajärvi National Park a thick glacifluvial system stretches from the eastern margin of Lake Paanajärvi eastwards as far as Lake Pyaozero (Paajärvi).

Glacifluvial deltas formed close to the retreating ice margin in the zone where meltwater flowed into periglacial water bodies. Glaciofluvial deltas in central and western Karelia cover areas of between several hectares and several square kilometres, their sand-pebble-boulder constituents varying in thickness up to 20–30 metres. It often took hundreds of years for deltas to form at locations where huge glacial meltwater discharge systems flowed into large water bodies, by which time the ice margin had retreated far away from the proximal margin of the delta. Such deltas are called extramarginal. Unlike common glacifluvial deltas that formed near the ice margin these extramarginal deltas are composed of finer sand and extend over 20–30 km^2. Their sand deposits are 50–60 metres thick. One such extramarginal delta is located on the north shore of Lake Pyaozero. Here a large glacifluvial system stretched along the present-day Oulankajoki – Lake Paanajärvi – Oulanka river system and flowed into the ancient White Sea basin. Another extramarginal delta of similar structure and size occupies the isthmus between lakes Palyeozero and Sundozero. It was formed at the point where the main meltwater discharge system flowed down the Suna river valley and the Gimoly lake basin into Lake Onega.

(Sand) outwash plains are of widespread occurrence in western Karelia. They formed near the melting ice margin during the Salpausselka stages I and II . Similar landforms occur near the western boundary of Vodlozer National Park where they are associated with marginal deposits generated during the Luga glacial stage.

All the above glacifluvial complexes are built up of sand, gravel and pebble deposits that are over 10–15 metres in thickness and possess good filtering properties. Resting on them are organically poor surface-podzol soils. The forests that grow on these soils are dominated by green moss pine stands. Rivers usually develop well defined valleys in sand sequences with meanders, oxbow lakes and two or three terraces above the flood plain. Where lacustrineglacial sand plains, outwash plains and extramarginal sand plains are common, sand is commonly transported and deposited by the wind to form dunes. Lakes are often nourished by highly mineralised underground water which contributes to the evolution of diatoms and the deposition of diatomites.

Late Pleistocene evolution of Karelia. Here we outline the main geologic events of the last global climatic cycle which gave rise to the present environment and biogeocenoses found in Karelia.

The **Mikulino Interglacial Period** (130–115 thousand years ago). About 130 000 years ago the penultimate ice sheet had melted in the mountains of Scandinavia and a climatic optimum of the Pleistocene epoch, known as the Mikulino Interglacial Period, took hold. After the waning of the Moscow (Saale) Glaciation tremendous volumes of meltwater and an glacioisostatic sagging of the territory triggered a large scale sea transgression. This is known as 'Boreal' in the Arctic Ocean basin and 'Eemian' in the Baltic Sea basin. In northern Karelia and on the Kola Peninsula, where the degree of downwarping caused by the Moscow ice shield was at its greatest, transgression reached the present-day hypsometric level of 100–120 metres and in southern Karelia of about 60 metres. The White Sea was connected through the Ladoga, Onega and Vyg basins to the Baltic Sea. The shells of *Mutilus edulis* L., *Tellina baltica* L., *Tellina calcarea* Chemn., *Leda pernula* Mill, *Portlandia (Yoldia) arctica* Grey and *Cardium ciliatum* Fabr., as well as those of the foraminifers *Buccella ex gr. Frigida, Elphidium subclavatum, E. ex Gr. Subarcticum, Cibicides ex gr. Rotundatus* and *Protelphidium orbiculare* (Geology of Karelia 1987) found in marine clay drilled near the shores of Lake Onega and in the White Sea-Baltic Sea Canal area suggest that the climate was then warmer than now. Sea relics, such as sea sculpin (*Myoxocephalus quadricornis onegensis*), *Limnocalanus*, higher Crustacea (e.g. mysids) and amphipods (*Gammaracanthus, Pallacea* and *Pontoporea*) were found in many water bodies that formed part of the boreal sea (Fig. 7) (Lakes of Karelia, 1959). Subsequent glacial advance ousted relict fauna southwards along the Vytegra-Kovzha and Volkhov-Lovat river systems to the extraglacial zone where periglacial water bodies with environments differing from those found today were prevalent. As the ice began to melt and the periglacial Onega, Ladoga and White Sea lakes gradually formed, the water bodies of Karelia became recolonised.

Maximum boreal transgression overlapped the climatic optimum of the Interglacial Period. Pollen and spore analysis of Karelian Interglacial deposits reveals a plant succession from Arctic desert and tundra (late stages of the Moscow Glaciation) to birch and pine stands (early stage of the Mikulino Interglacial Period) and coniferous-broad-leaved forests (climatic optimum), followed by the culmination of broad-leaved tree species such as oak, elm, hazel, lime, and hornbeam (Devyatova, 1972).

As a result of glacioisostatic crustal uplifting in the latter half of the Mikulino Interglacial Period the sea strait in the Onega-Segozero watershed area dried up. Later on freshwater bodies began to evolve in the Onega and Ladoga basins.

The abundance of dark-coloured Mikulino marine bituminous clay in the northern part of Lake Onega and along the White Sea-Baltic Sea Canal also affected the composition of younger Valdai and Holocene deposits. Redeposited sea shells are commonly found in glaciofluvial deposits close to Medvezhyegorsk. Ferrous-rich black and dark grey sapropels with a characteristic hydrogen sulphide odour often occur on the Zaonezhye Peninsula and in the Onega-Segozero watershed. According to I. Ekman (1995) their formation was the result of a number of factors including the presence of Mikulino black marine clay.

The **Valdayan (Weichselian) Glaciation** originated in the highlands of Norway about 115 000 years ago. Cold maxima occurred 90 000 and 60 000 years ago. During the latter the eastern front of the Scandinavian glacier covered Finnish Lapland while the southwestern boundary of the Kara ice sheet extended along the Kuloi Plateau and the eastern coast of the Kola Peninsula. There exists no well-documented evidence for Early or Middle Valdai glaciation in Karelia. The Scandinavian glacier margin presumably overlapped northwestern Karelia and periglacial conditions with tundra and forest-tundra landscapes dominated most of the region. Pollen records from interglacial deposits near Petrozavodsk lead to the conclusion that 30 000–45 000 years ago there was no ice in southern Karelia and that pine and birch forests mixed with broad-leaved species prevailed (Geology of Karelia, 1987). About 25 000 years ago Late Valdayan global cooling allowed the continental ice sheet to advance into the northern Russian plain. During maximum glaciation some 17 000–20 000 years ago the Scandinavian ice sheet boundary extended roughly along the Smolensk-Vologda-Mezen line.

The ice began to recede from Karelia approximately 16 000 years ago during the Vepsovian-Krestets stage (see Fig.1). Marginal deposits of this age extend from the Andoma Upland across southeastern Karelia as far as the Lake Kenozero area in the Arkhangelsk district. Areal type deglaciation prevailed during this period. During the subsequent

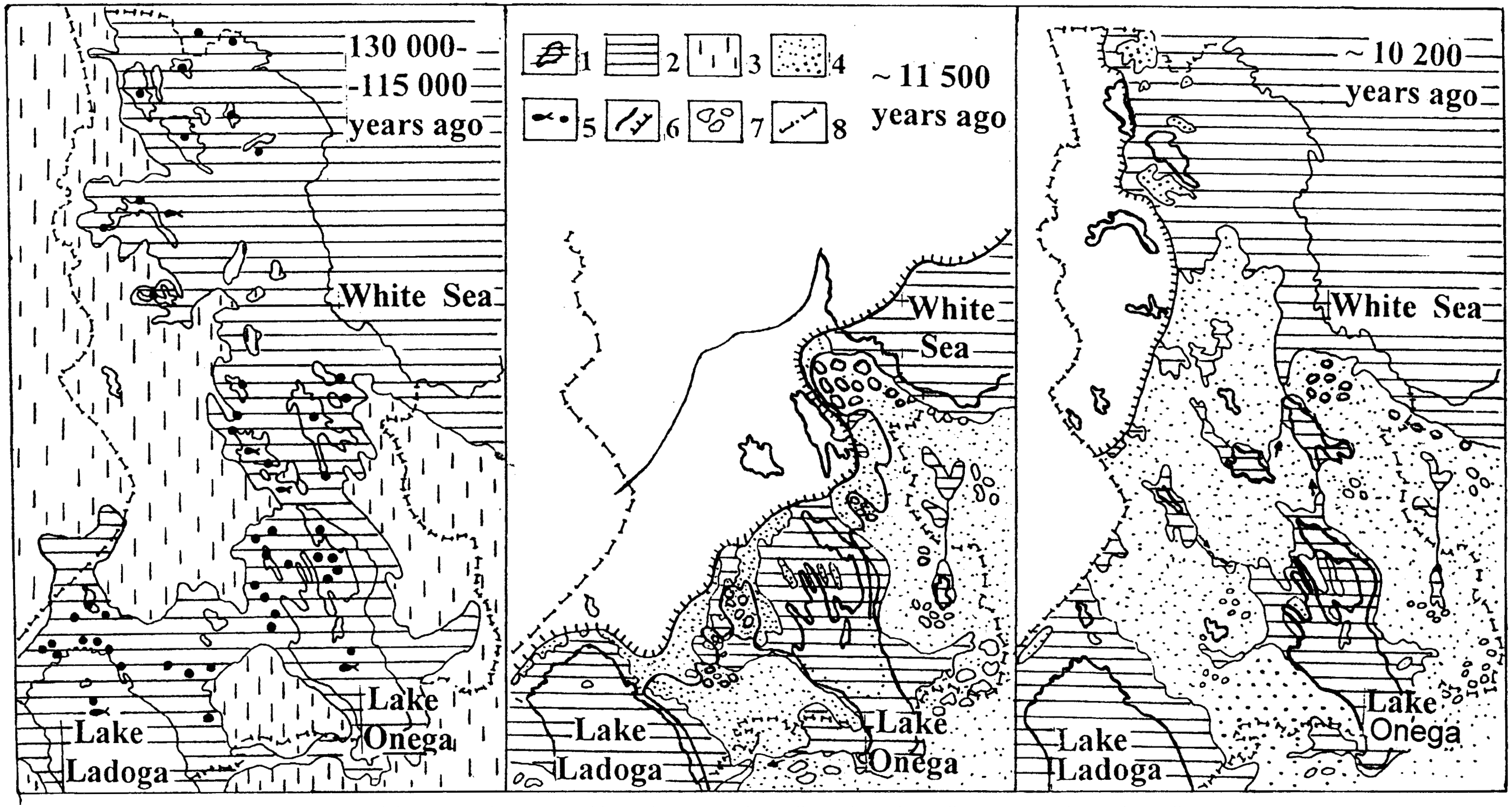

Fig. 7. Late Pleistocene palaeogeographic environment of Karelia (Lakes of Karelia, 1959; Geology of Karelia, 1987).

Symbols: 1 = modern water bodies; 2 = old marine and lacustrineglacial water bodies; 3 = forests; 4 = tundra and forest-tundra; 5 = distribution of sea relics of fish and crustaceans in lakes; 6 = ice-marginal positions; 7 = dead ice massifs; 8 = administrative borders of the Republic of Karelia.

Luga stage of glacial retreat (13 000–14 000 years ago) marginal deposits rimmed the Olonets Upland in southern Karelia and the Windy Belt Range in eastern Karelia. Being far from the centre of ice sheet the peripheral portions of the ice lobes gradually lost contact with the retreating ice. Thereafter they remained melting slowly for thousands of years. Vast fields of dead ice were formed in eastern Karelia near Kolodozero and in the vicinity of the Andoma, Sumozero, Vodlozero and Volozero uplands. In southern Karelia similar deposits were generated on the Urok Ridge and in the Olonets Upland. During this period large periglacial water bodies were formed in the Ileksa and Vodla river basins, in southern Lake Onega and, more recently, in the southern Shuya Lowland. It seems that this was the time when cold-resistant fish species started to reinvade Lake Onega which was then part of the Volga river basin.

During the cold Neva stage of glaciation (12.5–11.8 thousand years ago) ice lobes occupied the Ladoga and Syamozero basins as well as most of Lake Onega and the White Sea. As a result of climatic warming which occurred during the Allerod period (11 800–11 300 years ago) the structure of the ice sheet and environmental conditions changed considerably. Meltwater flowing from the rapidly downwasting glacier surfaces spread across the land to form hundreds of intricate glaciofluvial systems. In the large Ladoga, Onega and White Sea basins the water level rose and the ice lobes began to rise to the surface and detach as icebergs. A cutting type (i.e. in which ice first broke off from the main glacier and then melted in isolation) of deglaciation predominated at these localities. At Lake Onega, for example, the ice retreated at a rate of 25 km per hundred years (Demidov, 1997). It therefore took hundreds of years for the ice margin to recede 200–300 km, during which time the upper surface of the lobe-shaped ice sheet became smoother.

This period of time also saw the birth of large periglacial water bodies. Their sand-clay deposits persist on the shores of lakes Ladoga and Onega and in the Shuya, Vodla, Olonka and Onega river basins. At the same time ice was retreating from the vast territories which extended from northern Priladozhye to the Onega Bay section of the White Sea. Morainic plains with numerous esker ridge systems formed in these localities.

During the Alleröd period plant and animal communities reinvaded the newly deglaciated land surface. Thin birch forests predominated in western Karelia while in southern and southeastern Karelia the percentage of spruce pollen rose to 36% (Yelina, 1981). Communities were forming in spite of the cooling effect of the ice sheet as well as the existence of large dead ice and permafrost fields. The migration and mixing of ichthyofauna were favoured by 1) a considerable increase in the area of water bodies, 2) permanent alterations in their configurations and runoff thresholds, 3) the connection of Lake Onega with Lake Ladoga through the River Svir and, more recently, with the White Sea through the Onega-Segozero Strait and 4) the White Sea basin is free from glacier ice.

Cooling during the Late Dryas period caused the glacier to advance during the Salpausselka I and II stages and the ice margin advanced into western and northern Karelia. This brought about changes in both flora and fauna. The percentage of woody species in pollen and spore spectra for this period drops to 19–31%, with dwarf birch making up about 30% of this figure. Tundra and forest-tundra landscapes dominated in southeastern Karelia (Yelina, 1981). During the Late Dryas period ice blocked the straits connecting the Baltic Sea with the Atlantic Ocean to form the ice-dammed Baltic Lake. Its waters penetrated the Lake Ladoga basin and flooded coastal lowlands to almost 80 metres above the present sea level. At that time Lake Onega was still flowing out into the White Sea and was being replenished by glacial meltwater coming from the ice margin down the Gimoly lake basin and the present-day Suna river valley. Terminal end-moraine Salpausselka ridges and adjacent thick sand outwash plains were formed in western Karelia. The powerful glacifluvial system discharged meltwater through the Paanajärvi lake basin into the old brackish White Sea.

The **Holocene**. During the early Holocene epoch (10 000 years ago) the retreating ice left the Swedish Straits and made way for a link between the glacial Baltic Lake and the ocean. The water level dropped considerably and Lake Ladoga began to evolve as an independent lake. By about 9 500 years ago the ice had receded from Karelia. Glacial and glacifluvial erosion and accumulation were followed by weathering, paludification and a gradual drop in the level of large water bodies such as the White Sea, Lake Onega and Lake Ladoga, accompanied by small scale transgressions. About this same time as a result of glacioisostatic crustal uplifting the Onega-Segozero watershed was drained and water continued once again to discharge from Lake Onega down the River Svir (Saarnisto, et.al, 1995). This presumably caused the water level of Lake Ladoga to rise.

Rapid glacial waning and dramatic changes to the outlines and depth of periglacial water bodies contributed to a considerable glacioisostatic crustal uplifting accompanied by a number of powerful earthquakes. Traces of these in the form of large scale land-slips and other palaeoseismic dislocations may be found in the Zaonezhye Peninsula, in northern Priladozhye, in the White Sea region and in the West Karelian Upland (Lukashov, 1995).

It was not until the Boreal period (8 800–7 500 years ago) that substantial climatic warming began. This reached a maximum during the Atlantic period (7 500–4 500 years ago), which constitutes the climatic optimum of the Holocene epoch. Vigorous paludification began during the Boreal period and reached its maximum in the Atlantic period. Mean annual temperatures then exceeded present-day temperatures by 2–5 degrees and most of Karelia was covered by south-taiga spruce and pine forests mixed with broad-leaved species (Yelina, 1981). It was during this Boreal-Atlantic period that early man came to settle in the region.

1.5. Hydrological characteristics

The evolution and diversity of aquatic organisms depend largely on their environment, which, in turn, depends on the morphometric characteristics and qualitative parameters of water bodies present. Let us analyse the main characteristics of the regional hydrographical network, which exert a substantial effect on the evolution of biota.

General characteristics of environments in the hydrographical network. Karelia has a well-developed hydrographical network, which occupies part of the White Sea and Baltic Sea basins (Figs. 8 and 9). The White Sea portion covers 57% of Karelia and the Baltic Sea segment the remaining 43% (lakes Ladoga and Onega are not considered here). The hydrographical pattern of the region is primarily a result of its geological structure, relief, climate and geographic position.

Geologically speaking Karelia is located on the eastern margin of the crystalline Baltic (Fennoscandian) shield, which is dominated by Archean and Proterozoic rocks. Resting on them is a Quaternary cover composed mainly of glacial deposits together with interglacial and postglacial deposits that vary in thickness from 0 to 110–130 metres. Maximum thickness values occur in the southernmost part of the region.

Ancient tectonic processes followed by denudation and accumulation during the Quaternary period when continental glaciations became the dominating formative process generated major landforms. The formation of modern relief was mainly a result of the last (Valdai) glaciation which ended as recently as 10 000–11 000 years ago. The glacier brought and deposited tremendous volumes of assorted rock fragments or till. As a consequence a very specific and extremely rugged ridge-hilly relief with absolute altitudes of not more than 200 metres above sea level was formed. The highest altitudes of around 600 metres, e.g. Mount Nuorunen (577 metres), are to be found in north-western Karelia. Northwest oriented landforms are characteristic of southern Karelia. In the northern part of the region east to west oriented landforms prevail while those oriented towards the northwest and northeast are less common. Glaciations also affected the orientation of water bodies. Glacial activity and glacial waters shaped the preglacial relief without changing its major characteristics. The results of vertical tectonic movement accompanied by the uplifting and subsidence of the Earth’s crust are still visible today. During this period the basins of the White Sea and of Ladoga, Onega and other lakes were formed and river valleys occupied cracks and faults.

Karelia has a temperate continental climate, which incorporates certain maritime characteristics. Thus, the winters are long and mild while summers are short and cool. The degree of cloudiness is high and variable weather persists all the year round. Atmospheric precipitation, evaporation and a favourable precipitation-evaporation ratio are all of seminal importance in the formation of the hydrographic network and for the hydrology of individual water bodies. Karelia lies in an excessive moistening zone, i.e. a relatively low proportion of total precipitate evaporates. The climate is cool and cyclones are active throughout the year. Annual precipitation (550–750 mm) increases from north to south.

However, as summer temperatures are cool the degrees of cloudiness and of air humidity are both high. The degree of evaporation is relatively low, varying from 310 mm in northern Karelia to 420 mm in the southern part of the region. Thus, only 50–60% of precipitates evaporate and the remaining portion contributes to the formation of river runoff.

Geographic position is important as the region occupies part of the White Sea-Baltic Sea watershed and lies in between and in relatively close proximity to large base levels such as the Baltic Sea, White Sea, Lake Ladoga and Lake Onega.

The main determinants of the hydrographic network in Karelia are thus:

– the recent geologic origin of the network;
– the proximity to the surface of crystalline rocks and the thinness of unconsolidated Quaternary deposits;
– the large number of water-filled tectonic dislocations;
– a rugged relief of glacial origin;
– high atmospheric precipitation and low evaporation;
– the proximity of the main watershed to base levels.

Brief characteristics of the hydrographic network. All the above factors have contributed to the formation in Karelia of a hydrographic network as unique as that found in Finland. It consists mainly of numerous small and short streams and rivers, which link lakes to form lake-stream or lake river systems. Some of these such as the Kovda, Lenderka and Kamennaya-Nogeu systems have lake surface-drainage area ratios as high as 50–60%.

Some 26 700 streams and rivers with a total length of 83 000 km have been reported for whole of Karelia including the Karelian isthmus. 25 300 of these (95% of the total) are less than ten kilometres in length number. The total length of these streams is 53 300 km, in other words, 63% of total length in Karelia (Resources …, 1972). Only thirty rivers are over 100 km long (medium-length type). The average drainage density is 0.53 km/km^2. Most streams have small catchments areas. Only 366 water systems have basin areas in excess of 100 km^2, 51 systems having catchments areas of over 1000 km^2 and five systems (the rivers Kem, Vyg, Kovda, Vodla and Shuya) with catchments areas of 10 000 km^2.

Since Karelian streams and rivers are of recent origin and the crystalline basement retains some of its own characteristics, their channels are poorly incised, valleys are poorly developed and longitudinal profiles display stepwise patterns of alternating rapids and pools which often appear as expanded lake-like water bodies and lakes. The diversity of stream biotopes results in a highly varied aquatic flora and fauna.

Rapids of various sizes account for 80–90% of stream gradients. Karelian streams and rivers have relatively small gradients because major erosion bases are located near watersheds. In some small rivers, e.g. Neglinka, gradients are as high as 10 m/km, but gradients of 2–2.5 m/km predominate. Gradients may be little more than 1 m/km in larger rivers but can also be relatively high in certain stretches.

Narrow, low watersheds and the proximity of adjacent rivers, typical of Karelia, are conducive to the transfer of runoff into other basins. Thus, the River Suna discharges into Lake Palye while the nearby River Pongoma runs of

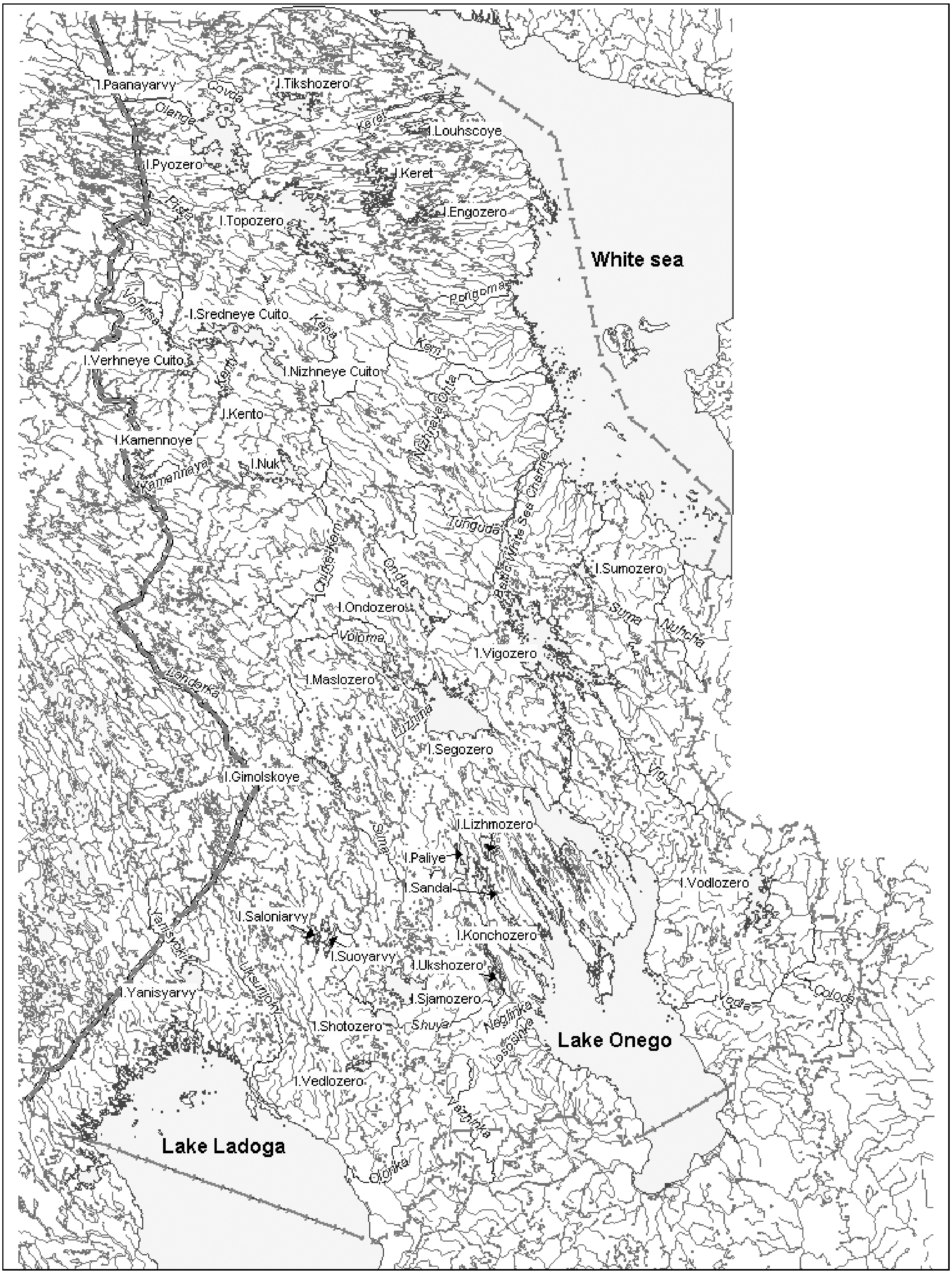

Fig. 8. Hydrographic network of Karelia

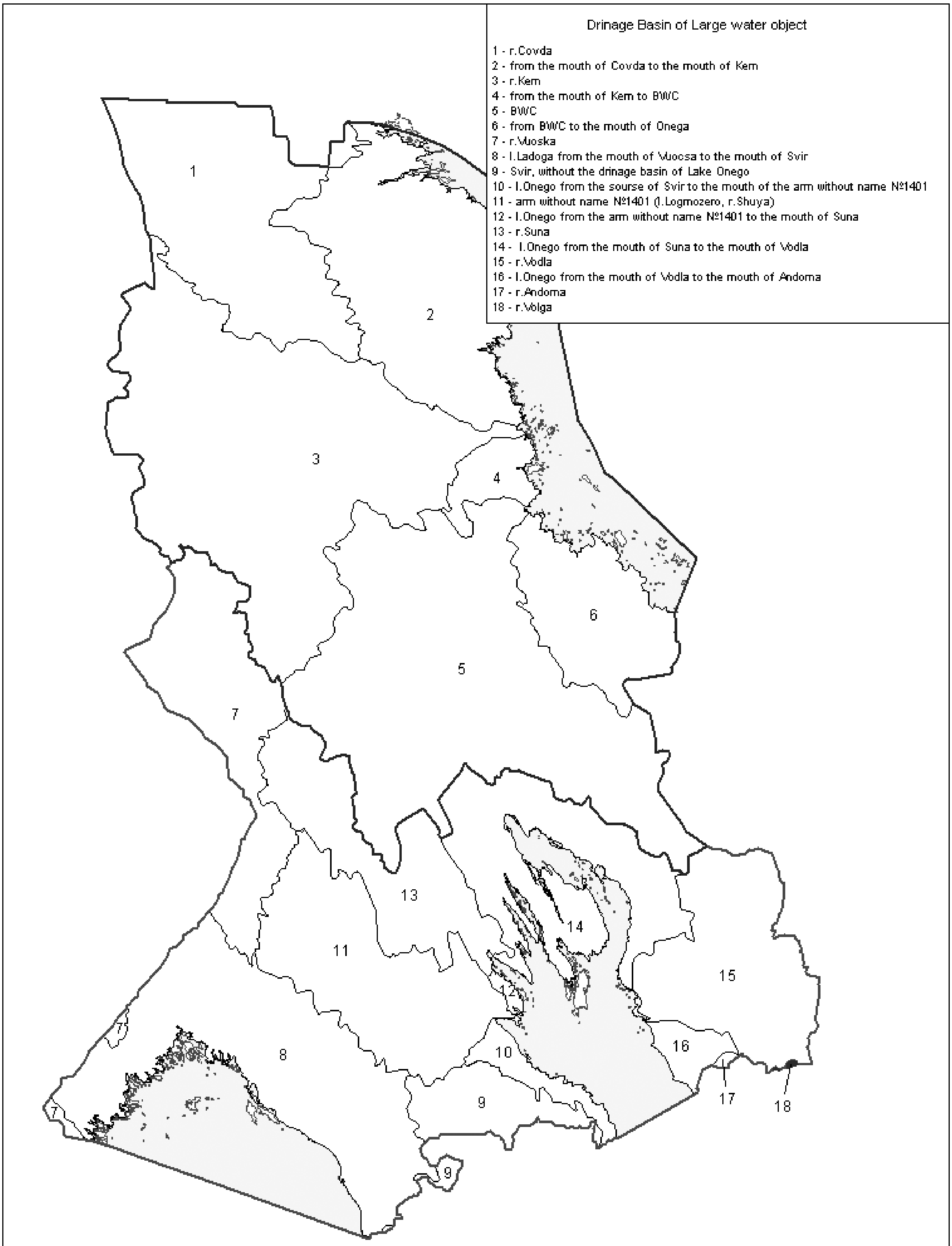

Fig. 9. Scheme showing the watersheds of seas and other large water bodies

into Lake Topozero. As the region has a rugged relief and major erosion bases are located close to watersheds, water flows out of lakes simultaneously in several directions. Thus Lake Engozero discharges along the rivers Kalga and Vonga, Lake Saarijärvi along the rivers Loimolanjoki (Tulemajoki) and Pensanjoki (Uksunjoki), and Lake Segezhskoye along the rivers Obzhanka and Segezha (a tributary of the River Svir).

The hydrographic network of Karelia consists mainly of water bodies such as lakes and reservoirs, which dominate the pattern of water systems. Karelia has 61 100 lakes which cover a total area of some 18 000 km^2 (Gasheva, 1967). In addition, approximately 50% of Lake Ladoga and 80% of Lake Onega, the largest water bodies in Europe, lie within Karelian territory. The region has a lake surface-drainage area ratio of 12%, a figure which rises to 21% if the Karelian portions of lakes Ladoga and Onega are considered. This is one of the highest ratios in the world (Karelia has a total area of 155 900 km^2, and of 172 400 km^2 including lakes Ladoga and Onega).

Lakes with an area of less than 1 km^2 predominate. Only 1389 water bodies (slightly more than 2% of the total number) are larger than this. Twenty lakes cover areas in excess of 100 km^2. Most lakes such as forest and mire ponds have no visible runoff.

Karelia has two major genetic types of lake basins: tectonic and glacial, or morainic. Almost all large and medium-sized lakes were generated tectonically. Lake basins were formed in cracks and faults that provide evidence of glacial erosion. They are typically deep, their shorelines are indented and their bottom relief is rugged. Small, 5–10 metre deep glacial lakes are located in troughs between morainic ridges and hills or in ice-dammed rivers valleys. They are characterised by a flat bottom and a less indented, often rounded shoreline. Their extensive, well heated, oxygen and nutrient-rich littoral zones has an environment conducive to the evolution of hydrobionts. Long narrow lakes cut by streams also occur. Lakes of mire origin are common.

One economic way of using water resources is to control river runoff by building reservoirs. It has already been noted above that geologically younger rivers in Karelia have shallow, poorly incised valleys. Therefore, valley reservoirs with riverbeds formed from parts of river valleys are necessarily small in spite of large-scale flooding. Almost all large Karelian lakes have been converted into reservoirs, whereas most reservoirs elsewhere in Russia and, indeed, in the rest of world are of the valley type.

The **chemical composition of surface water** is affected by the low solubility of crystalline bedrock, the presence of well-washed Quaternary material and large-scale paludification. Subsurface waters are usually poorly mineralised, have a high colour index and are rich in iron.

Available data was processed statistically and average quality indices for surface waters in Karelia were estimated. The sum of inorganic ions *(Σi)* is 22 mg/l. Throughout most of Karelia water has an *Σi* value of less than 25 mg/l and a hardness of 0.2–0.4 meq/l. Lakes and rivers with *Σi* 40–100 mg/l cover small areas. Only ten water bodies are known to have a total inorganic ion concentration of over 100 mg/l.

Cations. Calcium is the dominant cation in almost in all waters, magnesium being less common and sodium scarce. Greatest variations in concentration are observed for calcium. Potassium displays less variation and occurs only in relatively small concentrations (0.2–1.4 mg/l, average 0.53). In all waters alkaline earth metals dominate over alkali metals, thus providing an optimum environment for hydrobionts.

Anions. Lowest anion concentrations (0.4–1.9 mg/l) were recorded for chlorides. Average anion concentrations in surface waters are about twice as great as those found in atmospheric precipitates. The concentration of sulphates is more variable (0.5–8 mg/l). Lowest concentrations are observed in highly humified waters where levels are lower than in atmospheric precipitates. Mires are able to retain sulphates, which undergo chemical reduction in mire conditions. The bulk of sulphates present in surface waters are of atmospheric origin although they may also be formed by oxidation of sulphide ores.

The most variable ionic components are hydrocarbonates (0 to 200 mg/l) and organic acid anions (less than 0.01 to 0.4 mmol/l). Increased concentrations of inorganic ions usually result from the leaching of calcium and magnesium carbonates from rocks. The total concentration of inorganic ions is usually twice that of hydrocarbonates. Thus, the surface waters of Karelia differ in mineral composition and, especially, in alkali (hydrocarbonate) content. It causes differences in the species composition of hydrobionts.

Organic matter. It has been noted above that organic anion content also varies greatly owing to the great variations in concentration of organic matter. Thus, colour indices range from 5 to over 300 mgPt/l, while permanganate oxidizability (COD $_{Mn}$) from 2 to 60 mg O/l. This latter variation is due to large-scale paludification and the transport of allochthonously derived organic matter into water bodies.

Average indices for organic matter content are as follows. Colour index: 90 mgPt/l, COD $_{Mn}$: 13.4 mg O/l, Corg 10.1mg/l, COD $_{Cr}$ (bichromatic oxidizability): 23.9 mg O/l. These values correspond to a transitional state between mesohumous and mesopolyhumous conditions. A large part (up to 35%) of Karelia contains mesohumous waters, i.e. waters with moderate concentration of organic matter, colour indices of 35–80 mgPt/l and permanganate oxidizability values of 8–15 mg O/l. Twenty per cent of Karelian water bodies are rich in organic matter (mesopolyhumous), have a colour indices of 80–160 mgPt/l or greater and COD $_{MN}$ values of 15–30 mg O/l or greater. Low-humus waters also account for about twenty percent of all waters. Such oligohumous waters have colour indices of below 35 mgPt/l and COD $_{MN}$ values of under 8 mg O/l.

Hydrogen activity varies from pH 4.07 to 8.34, depending on the concentrations of HCO3?, CO2, organic acids and their salts. As concentrations of carbonic acid depends on water temperature the pH value is related to the proportions of HCO3?, RCOO? and RCOOH occurring at a given. The majority of surface waters in Karelia may be classified as low acidity (pH 5.5–6.5) or circum neutral (pH 6.5–7.5). The lowest pH values (< 5.5) occur in highly waterlogged areas and in small lakes supplied with atmospheric nutrients. Iron concentrations in surface waters vary from < 0.01 to 3.1 mg/l, the average value being 0.59 mg/l.

Classification and mapping of surface waters on the basis of quality. Surface waters may be classified according to quality, thus: high quality, good quality, satisfactory, poor quality and polluted (Litvinenko et al., 1998). This classification is similar to the one accepted in Finland but differs in its approach to and criteria for assessment of water quality.

Surface waters in Karelia are classified on the basis of several indices: the pH value and the concentrations of organic matter, iron, total phosphorus, chlorophyll-*a* and oxygen. Some of these parameters, such as the concentrations of total phosphorus, chlorophyll-*a* and oxygen, indicate the trophic status of the water body. The colour index of water indicates the amount of organic matter present of humus origin. This commonly makes up the bulk of all organic matter present in water bodies in Karelia. Closely associated with this index is the total concentration of iron. This parameter is used in the classification because a) surface waters are rich in total iron and b) its highest allowable concentration for drinking water is relatively low, i.e. 0.3 mg/l. The pH value is used to assess surface water acidification, which is a characteristic of the region.

Alkalinity and pH of water. Because surface waters are poor in alkalis they are often acid. pH values of 6.0–6.3 mark a transition from neutral to slightly acid water. At this pH the alkalinity of water is about 0.05 mmol/l. Water bodies of such alkalinity are susceptible to acidification. Slightly acid (pH 5.3–6.3) and acid (pH < 5.5) water is associated with the accumulation of labile forms of metals. This is unfavourable for hydrobionts, especially in naturally or anthropogenically acidified lakes. The most serious occurrence in such lakes is the accumulation of mercury in fish. Therefore, all acid lakes (pH < 5.5 and alkalinity > 0.01 mmol/l) are classified as containing water of poor quality. This is equally true of oligohumous (colour index < 35 mgPt/l.), mesopolyhumous (colour index 80–160 mgPt/l.) and polyhumous (colour index > 160 mgPt/l.) waters. It should be noted that, in practice, mesohumous acid lakes do not occur. Oligohumous acid lakes are acidified by atmospheric precipitation resulting from human activities. Such lakes are usually located in interfluvial areas and have small specific water catchments values (< 3). In these cases atmospheric nutrition is of considerable importance. Because mesopolyhumous and polyhumous lakes are situated in highly paludified areas their acidity is of natural origin. With the exception of polyhumous waters, all lakes and rivers with pH 5.5–6.2 are classified as having satisfactory water quality regardless of their organic matter content. From the point of view of drinking water the quality of ‘light’ water is considered to be better than that of humified water. In these cases the adverse effects of low pH on fish populations is considered. Russia has its own allowable range (pH = 6.5–8.5) for lakes and rivers for commercial fishery. Polyhumous slightly acid water bodies (colour index > 160 mgPt/l., pH < 6.2) are classified as poor quality because their waters are acid and contain large quantities of humus.

Total phosphorus. If the water is to be classified as high or good quality then its organic matter content and pH must be estimated as well as the concentration of total phosphorus, a major nutrients which affects the trophic levels of water bodies.

The concentrations of biogenic elements in water constitute a significant limnological index, which affects the productivity and trophic status of water bodies. In a natural environment trophic levels vary from oligo- (poorly productive) via meso- (moderately productive) to eutrophic (highly productive). According to total phosphorus content water bodies may be subdivided into oligotrophic (up to 12 µg/l of total phosphorus), mesotrophic (8–25 µg/l) and eutrophic (more than 25 µg/l). When biogenic elements are supplied with drainage water or washed out from fields, eutrophication is enhanced. Provided all other indices are favourable, oligotrophic water bodies are classified as high quality, mesotrophic waters as good quality and eutrophic waters as satisfactory. Highly eutrophic water bodies are classified as being of poor quality.

Oxygen. When discussing the trophic level of a water body the effect of the oxygen concentrations on the vital activity of fish should be taken into account. The minimum allowable concentration of oxygen accepted in Russia for commercial fishing water bodies in winter is 4.0 mg/l or 60% saturation. Oxygen saturation levels of 80–105% are considered to be most favourable. Such values are typical of all oligo- and mesohumous water bodies. Oxygen saturation levels of 60–120% testify to a good oxygen regime. An excess of oxygen in water as observed commonly in eutrophic lakes is caused by enhanced nutrient supply. Lack of oxygen usually occurs in the bottom layers during the vegetative season and during winter stagnation because bottom sediments use oxygen.

The unfavourable oxygen systems observed in highly eutrophic and eutrophic lakes are characterised by an excess of oxygen in surface layers (levels rising by up to 40%) and the absence of oxygen near the bottom. A lack of bottom layer O_2 and excess of surface layer O_2 is observed during summer stagnation while a sharp deficit of O_2 occurs near the bottom by the end of complete freezing in both eutrophic and mesotrophic lakes where bottom deposits use a lot of oxygen.

To sum up, all oligohumous (colour index < 40 mgPt/l) and oligotrophic (P_{tot} < 12 µg/l, chlorophyll–*a* < 3 µg/l) water bodies containing less than 0.2 mg/l Fe, with pH 6.5–8.0 and 80–105% oxygen saturation are classified as **high quality waters**. Examples of such waters include some large deep water bodies, e.g. a large part of Lake Onega, lakes Segozero, Maslozero, Yelmozero, as well as smaller lakes with a slow rate of water exchange such as the Konchezero group of lakes, lakes Lizhmozero and Kedrozero, etc. (Fig. 10).

Good quality waters are 1) mesohumous and mesopolyhumous (colour index 30–120 mgPt/l); 2) oligo- and mesotrophic (P_{tot} 8–25 μg/l, chlorophyll-*a* up to 10 μg/l) water bodies with pH 6.2–8.5, Fe concentrations of 0.1–0.5 mg/l (up to 0.75 mg/l provided P_{tot} is low and colour index less than 120 mgPt/l) and oxygen saturation levels of 60–120%. Such waters are typical of a larger portion of the basins of the Suna, Janisjoki, Tulemajoki, Lenderka and Svir rivers as well as of lakes Ladoga, Syamozero, Ondozero, Leksozero, Tuulos and Janisjärvi, etc.

Satisfactory water quality is found in 1) water bodies with pH 5.5–6.2, 2) eutrophic waters ($30 < P_{tot} < 50$ μg/l, 10 < chlorophyll-*a* < 30 μg/l), regardless of other indices, and 3) polyhumous waters with pH > 6.5, Fe concentrations of 0.5 to 1.5 mg/l and colour indices of up to 200 mg/l. Satisfactory waters include 1) most of the water bodies with paludified catchments areas such as the Shuya, Onezhskaya and Vidlitsa rivers, the central and southern portions of the Vygozero reservoir, etc., 2) small lakes with atmospheric nutrition, e.g. Lizhmenskoye, Kaskesnavolok and Langozero, and 3) eutrophic lakes such as Vedlozero, Svyatozero and Pryazhinskoye.

Poor quality waters are those with 1) pH < 5.5 regardless of other indices, 2) polyhumous water bodies with pH > 6.5 and Fe concentrations higher than 0.7 mg/l, and 3) highly eutrophic lakes ($P_{tot} > 40$, chlorophyll-*a* > 30μg/l). Low quality water is characteristic of 1) water bodies located in highly paludified areas, e.g. the upper stretches of the Shuya, Verkhny Vyg, Koitajoki, Olonka, Tuloksa, Enyajoki river basins etc., 2) small lakes located in interfluvial areas and those acidified by human activities (Chuchjärvi, Kivijärvi etc.), and 3) highly eutrophic lakes such as Kotkozero, Pyalozero and Shangima. (Fig. 10).

Polluted waters are understood as water bodies or parts of water bodies polluted by industry or agriculture. They typically exhibit excessively high BOD values together with unacceptable concentrations of P_{tot}, K, Li, heavy metals and oil products, etc.

1.6. Soil cover

Soil-forming conditions. Karelia is located in the eastern part of the crystalline Baltic shield which borders the Russian plain and is built of Precambrian granite gneiss and granite. 10 000-12 000 years ago the ice sheet which covered the whole region during the latter stages of the Valdai Glaciation finally retreated. Thus, soil-forming processes in Karelia are of relatively recent occurrence with soils developing on Quaternary deposits (Geology of Karelia, 1987). The composition of Quaternary material is affected indirectly by bedrock composition and directly by exposed bedrock.

Geological conditions profoundly affect soil formation. The last glaciation in Karelia led to the extensive deposition of coarse sand and loamy sand. Their light mechanical composition is a consequence of very slow chemical weathering.

The region has a distinctive geomorphological structure and a relatively cold and humid climate similar to that of cold and humid oceanic regions. This results from the proximity of large water bodies such as the White Sea, Lake Onega and Lake Ladoga. Favourably affected by the Gulf Stream, the climate of southern Finland is warmer than that of Karelia. Such climatic characteristics had a considerable influence on the formation of soils and soil cover. The soil profile of southern Finland is characteristically thicker and humus accumulation and Carbisol formation are both more prolific than in Karelian areas of corresponding latitude. Primitive soils are far more common in northern Finland and on the Kola Peninsula than in Karelia because bedrock exposures are widespread in those regions. Karelia has numerous lakes and rivers as its river valleys are poorly developed and its depressions enclosed. In this respect Karelia resembles Finland and northern Sweden where wet soils are common. (Äyräs et al., 1997).

In terms of the structure and composition of bedrock, the genesis and composition of unconsolidated outwash, and the age of its landscapes and soils Karelia resembles the Laurentian soil province in the boreal zone of Canada (Glazovskaya, 1973). In particular, Laurentian and Karelian share much in common. Although Karelia is slightly further north than most of the Laurentian province the same soil types occur in both regions owing to the similarity of their climates.

Soil formation pattern. The soil cover of Karelia (Fig. 11) consists of macro and mesocombinations of *Podzol* (henceforth soil names in this text correspond with the FAO-UNESCO classification, 1990), *Cambisol*, *Gley Podzol* and *Histosol* types. As Karelia contains a variety of landforms and soil-forming rocks its soil cover is highly mosaic-like and soils occur in complex combinations.

A moderately cold, humid climate, the predominance of light soil-forming rocks and the prevalence of coniferous forests in Karelia are conducive to the large-scale formation of eluvial-illuvial soils in automorphic environments. *Podzols* (60.8%) cover unconsolidated Quaternary rocks, *Cambisols* (0.9%) rest on mafic eluvial-deluvial rocks or on a till blanket rich in these rocks, and *Leptosols* (0.8%) or poorly developed soils (1.3%) accumulate on bedrock (Morozova, 1991). As Karelian soils are of fairly recent genesis almost no crystalline rock eluvium has formed and the primary soils beneath lithophilous plants growing on massive crystalline rock exposures are very thin. Various types of *Gley Podzols* are formed under semi-hydromorphic conditions. *Podzols* and *Gley Podzols* are dominated by sandy and loamy sand varieties. Loamy and argillaceous soils make up less than 6% of the Karelian land surface. *Fibric* (10.8%) and *Terric-Fibric* (8.2%) *Histosols* are of widespread occurrence. *Terric* soils make up not more than 1% of total land area.

The study region extends over a large distance from north to south. The north-taiga and mid-taiga subzones border one another at about 63° N. Soil-forming processes do not vary dramatically between these two subzones due to the abundance of soil-forming rocks which are of light mechanical composition and possess similar physical and chemical properties. These include a low moisture capacity, high water permeability, poor nutrient supply and an abundance of primary minerals. These factors offset variations in bioclimatic indices. However, some differences in soil-forming processes and soil cover do exist between the two subzones.

Characteristics of north-taiga soils. The soil profile of the north-taiga subzone tends to be thinner and the soils more skeletal and bouldery. Soil-forming processes are active in the uppermost 40-60 cm portion of soil-forming parent material (Fedorets, Erukov, 1997). Moreover, some unique soils occur only in this part of the region.

In northwestern Karelia where some ridges reach altitudes of up to 600 metres above sea level a clear pattern of vertical zoning occurs and *Hapto-Lithic Podzols* and *Lithic Leptosols* appear. These mountain soils are poorly understood and in Karelia are found only in the northwestern part.

The formation of soil cover in the north-taiga subzone is profoundly affected by the proximity of the White Sea. The present transgression and regression of sea water and the associated moisture content of soils in the tidal zone has contributed to the formation of unique *marsh soils* (*Salic Fluvisols*). These soils are rich in chlorine, sulphur and water-soluble minerals substances atypical of *Podzol* soil zones. They contain high percentages of organic matter throughout the entire profile and display a high degree of biodiversity as mineral layers alternate with algal laminae. As they are most commonly occupied by grasslands their sod horizons are well developed. On the White Sea coast *Salic Fluvisols* alternate with primitive types on bedrock outcrops. Primitive soils comprise only of a sod cover under motley grass or of forest litter in open pine forest.

Of common occurrence throughout the north-taiga subzone are *Epy-Histic-Gleyic Podzols.* These occupy not only topographic lows such as those in the mid-taiga subzone but also the flattened tops of morainic ridges and hills. This is due to the proximity of crystalline rocks which impede the free filtration of moisture. Furthermore, the occurrence of course, soil-forming sandstones contributes to the development of a humus-illuvial process.

Because the region has a cold climate, low evaporation and a consequently high moistening coefficient, *Gley Podzols* and *Histosols* cover over 40% of the north-taiga subzone. Histosols are dominated by a raised type of peat soil (Fibric Histosols) which accounts for 14% of all soils, with fen soils (Terric Histosols) occurring as individual massifs. Raised bogs in Karelia cover an area of about two million hectares (Soils of Karelia, 1981). As the Histosols that evolved on bogs are infertile and poor in microorganisms, the transformation and mineralisation of organic matter is retarded. Thus, territories covered by such soils are of low biodiversity. They are used only to a limited degree for commercial purposes although their forest-growing potential is, in fact, high.

Characteristics of mid-taiga soils. With the improved climate of the mid-taiga subzone soil-forming processes are active to a depth of 1.5–2 metres. Automorphous soils are more extensive while Gley Podzols and Histosols are only half as common (22%) as in the north-taiga subzone (40.5%).

Podzols make up two thirds of mid-taiga soil cover and are therefore the most common soil type in Karelia. They form on rocks poor in base and ferrugineous minerals and may vary widely in their mechanical composition and genesis. Thus, Podzols may consist of glaciofluvial and lake sand, till, sand or loamy sand deposits. They all contain small percentages of silt and mud particles. Till deposits are heterogeneous and bouldery. The formation of such soils is also connected with the abundance of coniferous forests in Karelia. The bulk of organic remains consists of ground litter-fall which is poor in ash elements and nitrogen. A lack of bases and an acid reaction, together with certain biochemical characteristics of plant remains (high percentages of resin, wax and lignin), result in a poorly developed microflora and the slow humification and mineralization of litter-fall. The mat reserves on the soil surface are 5–20 times that of annual ground litter.

As their soil-forming rocks differ in genesis and particle-size distribution, the species diversity of Podzols is high. Commonly restricted to fluvioglacial sand deposits are Surface Podzols and Ferric Podzols. They are poor in organic matter and mineral nutrients. Ferric Podzols and Ferric-Carbic Podzols are evolving on sand and loamy sand till. Their organic matter content is four times that of Surface Podzols. As the proportion of fine particles in the soil-forming rock increases, both soil fertility and biodiversity of the territory improve.

Generally speaking in Karelia, accumulation of humus in soils under forest vegetation is most commonly the result of human activities. As a consequence of swidden farming large forested areas were cleared and burnt and the upper soil horizons were enriched in mineral nutrients. Abandoned agricultural lands were overgrown with grasses which favoured the accumulation of organic matter in the soil and sod formation, and were later covered by forests. Nowadays, *Humic Leptosols* occur only in southern Karelia. Typically found growing on them are deciduous motley-grass forests mixed occasionally with conifers. This soil type usually has an accumulative horizon. *Humic Leptosols* are fertile, the humus content of the humus-accumulative horizon being 4.5–10% and the nitrogen content up to 0.7%.

Resting on heavier rocks are *Dystric Planosols*. They occur locally and are restricted to varved limnoglacial clay and loam exposures. As heavy rocks have a high moisture capacity and a low water permeability, upper soil horizons display an excess of moisture, especially in spring and autumn when evaporation is slower. As the environment in conducive to processes of chemical reduction, iron and manganese compounds are dissolved, soil minerals are destroyed and decomposition products dissolved. Humus accumulation and eluvial-gley processes occur although the layer involved in soil formation is generally only 20–30 cm thick. As *Dystric Planosols* are rich in humus and mineral nutrients they are typically covered by highly productive stands and their biological diversity is relatively high.

Forming on base-rich and ferrugineous soils are *Cambisols* (Targulyan, 1971). Owing to the high Fe, Ca and Mg contents of soil-forming rocks the mid-taiga subzone, especially its southern part, contains an abundance of *Dystric Cambisols*. As a result of the conditions prevalent in Karelia *Cambisols* are extrazonal soils. High percentages of iron and calcium in soil-forming rocks retard the formation of podzols so characteristic of the boreal zone and the entire soil profile acquires a brownish tinge. *Cambisols* are rich in organic matter and often have a well-defined granular-structured humus horizon. As *Cambisols* are rich in soil fauna the plant litter-fall is vigorously reworked and a moder or moder-mull type of soil profile is formed. It only takes a year or two for the plant litter-fall to decompose, and consequently *Cambisols* have a thin mor. This soil type is highly fertile and supports a high degree of biological diversity throughout its distribution area.

Of great interest are *Shungite Cambisols* which evolve on shungite (carbonaceous) shale eluvium or till containing a high percentage of shungite rocks. *Shungite Cambisols* are unique. They owe their high natural fertility not only to the organic matter resulting from the transformation of plant remains supplied to the soil but also to the carbon present in soil-forming rocks. *Shungite Cambisols* were known earlier as ‘Olonets chernozems’ because of their black colour. The horizons of their soil profiles are poorly defined. The well-developed root systems of herbs and the activity of soil fauna favour the formation of a fairly thick humus horizon. Owing to their black colour *Shungite Cambisols* absorb more solar energy and are therefore better heated (The study of forest soils in Karelia, 1987). As *Shungite Cambisols* resting on carbonaceous rocks are highly fertile the most biodiverse localities in Karelia are found on the Zaonezhye Peninsula where they are widespread (Inventory and study of biological diversity in the Zaonezhye Peninsula and in northern Priladozhye, 2000).

Another soil type occurring in Karelia comprises the *Leptosols*. These are soils with a brown, poorly differentiated profile which forms on crystalline rock eluvium or eluvium-deluvium. *Leptosols* are highly diverse, the degree of diversity depending on the environment in which they form, i.e. the thickness of the unconsolidated blanket, moisture supply and vegetation, etc. These quantitative differences are mainly observed in the humus state of the soils. *Leptosols* are fertile and occur only on a limited scale.

In the mid-taiga subzone of Karelia *Fibric Histosols* are succeeded by *Terric-Fibric* and *Terric Histosols*. The latter are rich in mineral nutrients. In Karelia these typically occur in tectonic bedrock faults. As *Terric Histosols* are supplied with highly mineralised water they give a slightly acid reaction and are rich in Ca, Fe and K. Being more fertile than other *Histosols*, their distribution area is floristically diverse.

Terric-Fibric Histosols result from the evolution of *Terric Histosols,* the upper horizons of which are no longer supplied with mineralised ground water. Impoverishment is most chiefly indicated by the presence of Sphagnum mosses in the vegetative cover. In terms of productivity *Terric-Fibric Histosols* are an intermediate type between *Fibric Histosols* and *Terric Histosols*.

Conclusion. To sum up, the most common soils in Karelia such as *Podzols, Gley Podzols* and *Histosols* are of low natural fertility. Therefore, a large part of Karelia is inhabited by low-productivity forest communities and has a fairly low index of biotic diversity. *Podzols* are highly acid and poor in mineral nutrients and organic matter. *Gley Podzols* and *Histosols* are rich in organic matter but are poor in mineral nutrients due to their poor water-air regimes and low biological activity.

Cambisols that form on the eluvium-deluvium of bedrock and on shungite (carbonaceous) shales are the most fertile since they are rich in organic matter and mineral nutrients and evolve in a slightly acid environment. Primitive soils resting on bedrock exposures are the least fertile type. North-taiga soils are slightly less productive than mid-taiga types.

The biodiversity of the study region depends largely on the ecological functions of the soil (Structural and functional role of soil in biosphere, 1999). The soil provides a habitat for an abundance of living organisms. Furthermore, it is a central link in the interaction of geological and biological cycles in the biogeosphere. Fertility is a key parameter in soil characteristics and is responsible for the diversity of terrestrial biota.

The biodiversity of any region can be maintained if its soils remain diverse. The soils of Karelia are dominated by *Podzols* and *Gley Podzols*. Soil types unique to Karelia are *Lithic Leptosols, Hapto-Lithic Podzols* and *Salic Fluvisols* in the north-taiga subzone, *Shungite Cambisols* in the mid-taiga subzone, and *Leptosols* and *Cambisols* which occur throughout the region.

Since some of the above soil types are not fertile, their distribution areas are not biologically diverse. However, as these soils have some specific properties of their own, rare plant and animal species atypical of Karelia are occasionally encountered there.

2. DIVERSITY AND CURRENT STATE OF ECOTOPES AND OF FOREST, MIRE AND GRASSLAND COMMUNITIES

2.1. Forests

2.1.1. Methods of studying biodiversity and the anticipated influence of commercial activities in taiga forests

Introduction. Over the past few years the problem of biodiversity has been the subject of lively discussion amongst biologists and ecologists. Numerous papers published in Russia and in other countries have sought to unify the methods used to study and assess the phenomenon (including «Biodiversity …», 1992; Biological diversity of forest ecosystems», 1995; «Biodiversity …», 1995; «Biodiversity …», 1996; «Global biodiversity», 1995; etc.). The present paper is an attempt to present the essence of the subject and to briefly formulate the principles by which it may be studied and by which solutions to problems may be found.

Definition of biodiversity. Biodiversity is understood in terms of the presence of biosystems, biological species, populations, genotypes, biotypes, phenotypes etc. at different levels in ecosystems of a particular taxonomic rank.

Elements of biodiversity, levels and criteria of assessment. Based on experience in forest biogeocenology, geobotany and forest and landscape ecology, the following methodological approaches to the study of biodiversity in the taiga zone were proposed.

I. Biodiversity assessment level: 1. Biosphere. 2. Continent. 3. Vegetation (geographic, climatic) zone. 4. Vegetation (geographic, climatic) subzone. 5. Vegetation (geographic, climatic) area. 6. Type of geographic landscape. 7. Type of biogeocenosis. 8. Type of microgroup.

II. Elements of biodiversity: 1. Plant formations. 2. Biocenoses (phytocenoses, zoocenoses). 3. Sinusia. 4. Consortia. 5. Plant and animal species. 6. Plant and animal populations. 7. Plant and animal genotypes and corresponding biotypes and phenotypes.

The above elements of biodiversity fall into two categories: 1) biosocial (formations, biocenoses, phyto- and zoocenoses, sinusia, consortia) and 2) genetic (species, populations, genotypes, ecotypes and phenotypes).

III. Criteria (features to be assessed) of biodiversity: 1. Age. 2. Composition. 3. Productivity. 4. Complexity of mosaic formation. 5. Occurrence. 6. Position within sequence of succession, etc.

The problem of a standard for diversity. Based on our experience in the study of primeval (climax – after Clements, 1916; exhausted – after Sukachev et al., 1964) and serial forest biogeocenoses in East Fennoscandia, we recommend that a biodiversity standard should consist of biocenosis-ranking primeval ecosystems and the higher rank biosystems formed by them. These are long-lived, stable biosystems which have fully adapted themselves to local natural and geographic conditions.

In territories where primeval forests have not survived, spontaneous serial forests in the stages of formation, quantitative maturity and natural maturity may be used as a standard. It should be noted that in order to establish a biodiversity standard for derivative forests further detailed study is required.

In terms of biological diversity the primeval forests of the taiga zone of European Russia display the following characteristics:

1. The presence of three major forest formations: pine, spruce and larch stands.
2. Largely hidden physiognomic differences between the forest phytocenoses of a given formation restricted to differing forest conditions.
3. Typical taiga flora comparatively poor in species.
4. Typical taiga bird and mammal fauna of comparatively poor species diversity and low populations alongside a relatively diverse dead-wood insect fauna.
5. Small berry plants and diverse mushroom flora.
6. A population structure of plant and animal species which has formed over millennia and adapted itself to local climatic conditions.
7. An exceptionally diverse gene pool of forest-forming species which has adapted itself to particular forest conditions.
8. Stands include trees of different ages. Communities typically comprise pine trees of anything up to 500–600 years, spruces up to 400–500 years and birch and aspen trees up to 150–200 years of age.
9. A high percentage of decaying trees and the permanent presence of dead standing and windfallen wood.
10. Stands exist in dynamic equilibrium.

Approach to the conservation of the rare and endangered biosocial and genetic components of biodiversity. In deciding which constituent from each element of biodiversity should be protected and what type of protection system is required the following points should be taken into account:

a. The evolutionary status of the element of biodiversity in question. Throughout the history of nature millions of species and types of ecosystems have come into being and then disappeared. Today also certain species and ecosystems are dying out while others proliferate. This is of great bearing in terms of their ecological and biological significance.

b. At what level of assessment (biospheric, zonal, biogeocenotic etc.) is the constituent (e.g. biocenosis, species etc.) considered to be rare or endangered? Thus, one particular plant species may be rare or endangered at a global level while a second is rare in the north taiga but common in the south taiga and yet a third scarce in white-stem moss pine stands but common in blueberry pine stands. Likewise a species may be common with respect to certain level of assessment (e.g. in the taiga zone) although its individual population or genotype is unique.

c. The biosocial role of a constituent. Let us assume that one particular cenosis is the only ecological niche for certain plant or animal species. Thus, one or other plant or animal species supports the existence of a trophically narrow specialised animal species etc.

d. Conditions for the reproduction of individuals of a given species, population or genotype.

e. The selective and genetic value of a species, population or genotype.

f. In order to survive anthropogenic transformation of their habitats animals need some areas of natural habitat to remain untouched.

All the above aspects should be thoroughly analysed in order to determine how and to what extent a given element of biodiversity should be protected during commercial operations in terms of level of biodiversity or area covered by a particular type of cenosis, species, population etc.

Regulation of biodiversity in human-disturbed ecosystems. It has been noted earlier that in primeval forest ecosystems biodiversity is typically stable whereas in human-disturbed (logged and managed) forest ecosystems all components, including practically all elements of biodiversity, exist in state of dynamic flux. Because of these differences between primeval and human-disturbed forest ecosystems different terminology is applied. Thus, biodiversity is ‘maintained’ in the former case and ‘regulated’ in the latter. The transformation of a human-disturbed forest ecosystem into a primeval one requires both the passage of a great period of time and an entirely spontaneous process of natural post-disturbance succession. Likewise, we can only regulate, not maintain, biodiversity in human-disturbed forests during commercial operations.

Various methods are used to regulate biodiversity in forests. However, at present these are applied only with respect to wildlife management. This involves varying final cutting, thinning and reforestation techniques and other biotechnical operations, etc. However, before a procedure for regulating biodiversity can be developed the biology and ecology of each plant and animal species within the ecosystem, their relation to one another and the effect of abiotic factors all need to be studied thoroughly along with the structure, dynamics and functions of ecosystems differing in rank, type, trophic links etc.

Changes in elements of biodiversity in taiga forests as a result of commercial operations: basic trends. The main forms of commercial activity affecting biodiversity in taiga forests are final felling, thinning, reforestation, drainage amelioration, forest fertilisation, biotechnical activities, recreation, indirect utilisation, etc. In order to estimate the anthropogenic impact on biodiversity primeval forest ecosystems were used as a standard.

Final felling. Current techniques of final felling techniques fall into several types: clear (concentrated and strip), successive and selective.

Concentrated clear felling has the most profound effect on biodiversity. As a result

- human-disturbed forest formations and forest biocenoses are generated;
- the age structure of forests as a whole becomes more diverse;
- new types of sinusia and consortia are produced;
- primeval forest ecosystems disappear while human-disturbed ecosystems evolve;
- open spaces with unequal cover of woody vegetation are formed;
- the vegetation cover becomes far more mosaic-like;
- food reserves for animals become much more widely available at given stages of post-catastrophic plant succession;
- taiga animal populations decrease and populations of animals associated with open and semi-open habitats increases at certain stages of post-catastrophic plant succession;
- there is an increase in the number and population sizes of southern species of flora and fauna and taiga features are only gradually restored by post-catastrophic succession;
- the population of most animal species increases sharply as more food becomes available, the edge effect increases and the vegetation cover becomes more mosaic-like;
- the species diversity of insects and fungi associated with dead wood declines.

In addition to the above other aspects of biodiversity are also affected. Thus, as a result of concentrated clear felling in the taiga zone the formational, biocenotic, sinusial and consortial diversity of ecosystems increases, plant and animal species become more diverse, the population and genotypic diversity of forest-forming woody plants is likely to decrease, and climax ecosystems are irretrievably lost. The extent of transformation of genetic diversity will depend largely on the type of reforestation activities carried out in felling areas.

Clear strip felling generally has the same effect on biodiversity in forests as concentrated clear felling but, with the exception of two particular elements of biodiversity, its impact is less severe. These two elements, namely, the population and genotypic structures of forest-forming species are affected to the same degree as in concentrated clear felling because the bulk of any given felling area lies away from the forest edge.

The effect of selective and successive felling on biodiversity is slightly smaller than that of concentrated clear felling although the genotypic composition of forest-forming species populations is still likely to be impoverished. The extent and pattern of impoverishment of gene pools of forest-forming species will depend on the felling pattern employed and the felling quality. If felling is carried out correctly fast-growing trees with high crowns and fully arboreal trunks can be expected to survive in commercial forests, all types of individual trees in water-protection and soil-conservation forests, and the most attractive individual trees in recreational forests. The genotypic diversity of cenopopulations is expected to change in accordance with the above phenotypes. When trees of the highest commercial value are the first to be cut, the resulting selection is both biologically and commercially detrimental.

Thinnings. The impact of thinnings on biodiversity in taiga forests depends on the felling pattern employed and the quality of felling.

The purpose of thinning in commercial forests is to produce a mature stand of maximum commercial value. Thinnings designed to produce high quality timber for economic purposes affect biodiversity in the following ways:

– forests retain their natural form since the emphasis is placed on growing coniferous stands;

– phytocenotic diversity decreases for the same reason;

– sinusial and consortial diversity in biogeocenoses declines as the proportion of deciduous trees decreases;

– the diversity of tree and plant species declines as most deciduous trees are cut down;

– light-demanding species are eliminated from the ground cover more slowly;

– the genotypic diversity of forest-forming plant populations decreases as decaying trees that endanger the commercial value of the timber are removed;

– the recovery of taiga fauna and flora from the ‘southernising’ effects of final cuttings is

– retarded;

– the process of succession of animal communities associated with open and semi-open sites by those typical taiga forest becomes slower;

– the species diversity of insects and fungi associated with dead wood declines.

If commercially valuable trees are the first to be cut then selection in the cenopopulations of forest-forming woody plant species will be biologically detrimental.

The purpose of thinning operations in water-protection and soil-conservation forests is to maintain the stand in a state which enables it to fulfil its intended functions most efficiently. Thinning in this type of forest is likely to influence biodiversity in the same way as in commercial forests, the only difference being that in water-protection and soil-conservation forests a narrowing of the genotypic spectrum of tree species can be avoided by preserving individuals of varying phenotypes and so allow the forests to fulfil their designated functions.

In recreational forests thinning is conducted in order to improve the recreational value of the area. The aesthetic quality of forest is thereby increased, bird and mammal species are encouraged and a high mushroom and berry yield ensured. Thinning can be expected to stabilise ‘southernised’ flora and fauna while also narrowing the genotypic spectrum of woody plant populations by removing forms of lesser aesthetic value and maintaining aesthetically valuable phenotypes.

Reforestation activities. These are understood to be steps taken in order to facilitate natural forest regeneration and the growth of forest cultures.

In forests formed in felling areas operations carried out in order to promote natural forest regeneration affect biodiversity in a variety of ways depending on the techniques used.

When undergrowth and thin conifers are not removed, formational diversity along with all categories of cenotic, species, population and – most importantly – genotypic plant and to a lesser extent animal diversity typical of primeval forests are transformed less markedly than during clear fell operations. The practice of leaving seed trees standing encourages the development of coniferous stands. As a result the original formational diversity together with all aspects of cenotic, species and population diversity are maintained. However the genotypic diversity of pine populations is decreased because only trees of the highest commercial value are left for seeding. When seed trees of spruce are left as patches the genotypic diversity of spruce populations does not generally decrease.

Coniferous forest cultures contribute to the maintenance of the formational, cenotic and species diversity of plants and animals. They also favour population and genotypic diversity of mammals and birds typical to primeval forests. The degrees of population and genotypic diversity depend on the origin of the seeds in question. If local seeds are used then no substantial changes in the population structure of pine and spruce would be expected. Thus, changes in the gene pool of these plant populations depend on the seed trees. If seeds are collected on permanent seed plots or in seed orchards then cenopopulations producing commercially valuable wood can be expected to develop. If seeds are collected from stands or felling areas during logging operations two alternative outcomes may be expected: a) the structure of the gene pool of the cenopopulation from which the seeds were collected remains unchanged or b) the spectrum of the gene pool narrows. This adversely affects the commercial value of the stock as trees producing the most seeds are usually those with well-developed crowns and, correspondingly, less linear trunks.

It has already been noted that in order to maintain the initial population and genetic diversity of woody species it is desirable to leave undergrowth intact when logging, irrespective of the quantity or even quality of the logging. If the undergrowth is not sufficiently dense then stand productivity may be enhanced by combining the remaining undergrowth with partial forest cultures.

Drainage of mires and paludified forest land. Drainage of land is one of the most efficient ways of increasing the productivity of forests. As a consequence both abiotic and biotic constituents of forest ecosystems are profoundly transformed. Forest drainage affects the biodiversity of forests in the following ways:

– forests become phytocenotically more diverse as forest phytocenoses forming on drained land generally possess unique structural and functional characteristics of their own and therefore have no analogues on either mineral soils or on paludified land;

– an original fauna forms which combines the characteristics of mire, mineral soil and paludified forest fauna;

Forest fertilisation. The impact of forest fertilisation on biodiversity in taiga forests is in principle similar to that of drainage reclamation and differs only in the pattern of the biogeocenotic process in initial and transformed ecosystems. Forest fertilisation affects biodiversity in the following ways:

– as trees grow faster and the crown canopy becomes denser, the dwarf shrub-grass-green moss cover on mineral soil types of forest is transformed into a dwarf shrub-green moss type. When fertiliser is applied repeatedly a green-moss cover succeeded by a dead cover is formed. As a result the ground cover becomes less diverse and incorporates some taiga species;

– glades and gaps become occupied by woody plants and filled with the vigorously growing crowns of surrounding trees. The composition and availability of food resources change and the fauna develops certain taiga features, usually becoming less prolific. One exception is the wood grouse or capercaillie which feeds off needles in fertilised pine stands and is thus able to maintain its populations;

– as fertilisation gives rise to biocenoses that have no counterparts in nature it should therefore be interpreted as increasing the biocenotic diversity of forests.

Indirect utilisation of forests. This includes the picking of berries and mushrooms, hay-mowing, grazing, hunting, collecting medicinal and non-arboreal plants, etc. Most types of indirect use such as picking mushrooms and berries, collecting non-arboreal plants etc. cause only minor disturbance to mammals and birds. However, hunting, grazing, hay-mowing and the collecting of medicinal herbs produce an adverse impact on biodiversity.

Unregulated hunting may lead to poor species diversity, the disappearance of certain species and populations and the impoverished genotypic diversity of game animals.

Unlimited grazing is likely to adversely effect the species diversity of plants and animals, especially birds. Animals are disturbed and the ground cover, an essential constituent of habitats, is often radically transformed or even destroyed.

Hay-mowing often increases both species diversity and most animal populations in biocenoses due to the resulting mosaic-like character of the habitats formed as well as the enhancing edge effect. The detrimental effects of haymaking in the taiga zone are relatively small as the hay-making season occurs in July-August when birds have already fledged and largely dispersed from their breeding grounds.

If the collecting of medicinal plants is not restricted the contribution of these to phytocenosis may decline. In critical cases their cenopopulations and even populations may disappear completely.

Biotechnical activities in forests. The purpose of biotechnical activities in the narrowest sense is to increase the biological and economic productivity of hunting areas. In broader terms it is intended to promote the species, population and genotypic diversity of animals. Biotechnical activities are carried out in order to improve living conditions, to help animals through the winter season, to prevent disease, to protect them against harmful environmental factors such as predators, competitors and human activities, to establish nesting grounds, etc. The results of such work will depend on its quantitative and qualitative characteristics and in all cases the possible consequences of human intervention should be thoroughly analysed. The provision of favourable conditions for one particular animal species can cause an imbalance in the biosystem and thus disturb other animal populations and plant diversity.

Recreation. In order to estimate the impact of recreation on biodiversity, unregulated and regulated forms of recreation will be discussed separately.

Unregulated recreation has a deleterious effect on biodiversity. As the ground is trampled down some plant species in the ground cover may disappear in biocenoses and even in entire landscapes. Likewise, those mammal and bird populations most vulnerable to disturbance are likely to dwindle or even disappear from their respective biocenoses or landscapes.

Regulated recreation entails the delineation of restricted and free access areas, the outlining of itineraries for guided tours, the establishment of open and semi-open sites of scenic value and artificial nesting grounds, and the introduction of new woody plant species. Adverse effects on natural biodiversity may be minimised while the species diversity of plants and animals typical to open and semi-open habitats often increases.

Conclusion. The present paper is an attempt to systematise the study, assessment and maintenance of biodiversity in forest ecosystems. The author does not believe his results to constitute any kind of absolute truth but rather that the work undertaken represents a step towards the correct assessment, maintenance and control of biodiversity.

2.1.2. Present state of the forest cover

General characteristics of forest growth. Karelia is located in the taiga zone in north-western European Russia. As a consequence of the latitudional extent of its territory there exist noticeable differences in climate and vegetation between its northern and southern parts. Thus, the region extends 672 km from north to south and 400 km from west to east (at the latitude of Petrozavodsk). Its total area amounts to 172.400 km^2. A line passing from Karhumaki to Porosozero divides the territory into two belts of vegetation, namely, the north-taiga subzone and the mid-taiga subzone. The larger part of the territory lies in the north-taiga subzone. Summer is short and cool while winter is long but usually free of extremely cold temperatures. Cloudy weather is common with both relative air humidity and precipitation high (400–650 mm/year). The mean annual air temperature is about 1° C, varying from 0.5° C in northern Karelia to 2.2° C in southern Karelia. The lowest air temperatures occur in February and the highest in July. The growing season is almost one month shorter in northern Karelia than in the south and growing conditions of woody plants gradually deteriorate on moving from south to north.

The glaciation which affected the present territory of Karelia destroyed all vegetation. After glacial retreat the land became colonised by typical tundra plants which later gave way to willow and birch forests. These, in turn, were succeeded by pine forests. At the same time, spruce stands containing typical tundra plants became established. Pine and spruce forest began to form between eight and nine thousand years ago. During the warm postglacial period certain broad-leaved species such as lime, wych elm, smooth elm and Norway maple appeared in spruce forests and Siberian larch penetrated the easternmost part of Karelia.

Characteristics of present vegetation cover. Forest is a basic biotic constituent of Karelian landscapes. The so-called forest fund, which incorporates small parts of the largest water bodies, covers over 85% of the region and over 95% of the entire forest area. According to the latest data the total land area covered by the forest fund is 14 760 200 ha. Forest land occupies 9 694 700 ha (65.7% of total forest fund area). The total forested area amounts to 9 267 400 ha (62.8%) (Fig. 12). Total wood reserves are 919.23 million cubic metres of which softwood reserves account for 814.13 million cubic metres. Characteristic of Karelian forests is the high percentage of treeless land (34.3%). 97.7% of such land is occupies by mires and water bodies. The overall percentage of forest coverage is 53.8%.

Species composition of forests. The composition of coniferous forests in Karelia is relatively poor in terms of species variety. Pine stands consist of Scotch pine (*Pinus sylvestris* L.) while spruce stands are dominated by common spruce (*Picea abies* (L.) Karst*)*. Siberian spruce (*Picea obovata* Ledeb.) occurs chiefly to the east of the White Sea-Baltic Sea Canal and Lake Onega. Finnish spruce (*Picea x fennica* (Regel) Kom) is widespread as an intermediate form between the above-mentioned species. Siberian larch (*Larix sibirica* Ledeb.) and Siberian cedar (*Pinus sibirica* Du Tour) have been introduced to southern Karelia in small quantities since the late 1950s. In the Kondopoga and Pryazha districts there are small Siberian larch stands established in the late 1930s. In the Kondopoga and Pudozh districts natural phytocenoses mixed with Siberian larch cover an area of about 17 ha. The deciduous forests of Karelia consist of silver birch (*Betula pendula* Roth.), white birch (*Betula pubescens* Ehrh.), aspen (*Populus tremula* L. and grey alder (*Alnus incana* (L.) Moench) mixed with coniferous species. Common alder (*Alnus glutinosa* (L.) Gaerth) is encountered occasionally in paludified spruce stands growing along streams in southern Karelia. It predominates in some 500 ha of stands in this habitat.

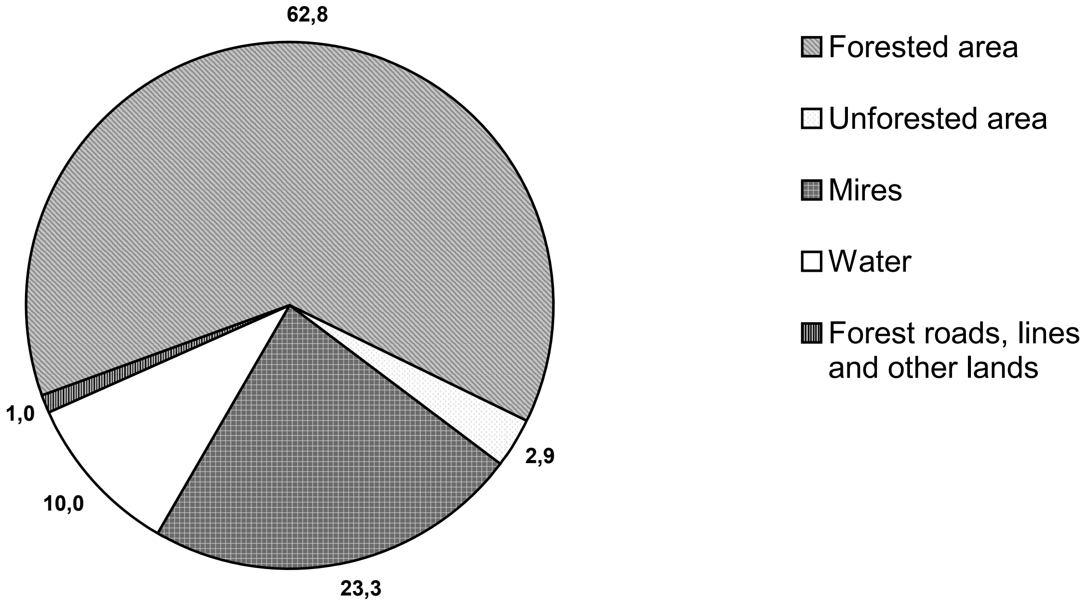

Fig. 12. Forest Fund area of Karelia by land categories, %

Another tree species growing in southern Karelia is Karelian birch (*Betula pendula* Roth., *f. carelica*). This is most common in mixed stands formed on abandoned swidden farmlands. Karelian birch occurs in seventy areas either individually or in groups of tens (less commonly hundreds) of trees. It is a strictly protected species. Most Karelian birch reserves are located in the Lake Onega basin. This birch species is also cultivated. On the Zaonezhye forestry seed farm forest with a high proportion of Karelian birch covers an area of 1360 ha.

In southernmost Karelia small-leaved lime (*Tilia cordata* Mill.), wych elm (*Ulmus scabra* Mill.*)*, smooth elm (*Ulmus laevis* Pall.*)* and Norway maple (*Acer platanoides* L.*)* grow locally on more fertile soils. However, they are very sparse in the woody layer and are commonly restricted to the undergrowth.

The forests of Karelia are made up of pine, spruce, birch, aspen, grey alder and common alder formations. Siberian larch, Siberian pine and common alder are cultivated on a small scale. Pine covers 63.8%, spruce 25.2%, birch 10.1%, aspen 0.7% and grey alder 0.2% of the forested area (Fig. 13).

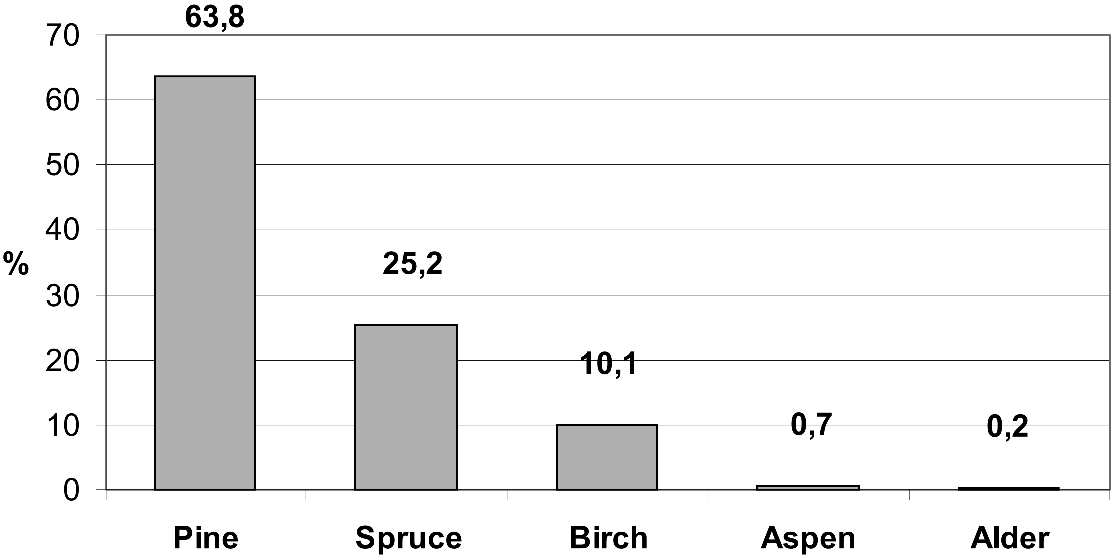

Fig. 13. Forest areas of Karelia by predominant tree species

Pine and spruce communities exhibit irregular distribution patterns. In the north-taiga subzone, where podzolised sandy and rocky soils prevail, pine stands occupy 78.3%, spruce stands 17.9% and birch stands 3.8% of forested area. Aspen-dominated forest cenoses cover a total area of 1 300. ha and grey alder-dominated communities only 100 ha.

In the mid-taiga subzone, where less podzolized loamy and clay soils and mesotrophic mires predominate, the percentage of spruce stands increases to 37%, that of pine stands decreases to 42.8% and that of birch stands rises to 17.8%. Aspen and alder account for 1.6 and 0.8% of forested area, respectively.

Mixed stands are commonplace. Thus, for example, pine stands generally incorporate 10–30% spruce and 10–20% birch. However, most lichen-type pine stands are not mixed. Spruce stands commonly include 10–30% pine and/or birch. Aspen accounts for 5–10% of bilberry (*Myrtillus*) forests.

Growing under the forest canopy are mountain ash *(Sorbus aucuparia* L.), juniper (*Juniperus communis* L.), wild rose (*Rosa acicularis* Lindl.), black currant (*Ribes nigrum* L.), red currant (*Ribes rubrum* L.), honeysuckle (*Lonicera xylosteum* L.), bird cherry (*Padus racemosa (*Lam.*)* Gilib.) viburnum (*Viburnum opulus* L.), buckthorn (*Frangula alnus* Mill.), mezereon (*Daphne mezereum* L.) and dwarf birch (*Betula nana* L.).

Age structure of forests. Ten to forty year old stands prevail (Tables 2 and 3), accounting for 40.6% of coniferous and 60.3% of deciduous forest area (Fig. 14 and 15).

Stands older than 100 years cover about one third of the total coniferous forest area. Pine and spruce stands varying in age from 240 to 260 years or over are included in the age group older than 160 years. Fifty to ninety year old forests are not common.

In deciduous forests there is a high proportion of trees older than 60 years. This type of age composition results from of relatively recent intensive clear felling operations. As a consequence, pine and spruce gave way to deciduous species, generally birch, over a large areas especially in the southern part of Karelia. In coniferous forests older than 120-140 years unequally dry dead standing trunks and unequally decomposed brushwood are always present. Dead wood provides a substrate for many wood-attacking fungus and insect species. The total mass of dead wood amounts to about 10–15% of that of living trees.

Table 2

Age structure of coniferous forests, 1000 ha / %

Stands (specified according to dominant tree species)	Age, years							Total
	< 20	21–40	41–60	61–80	81–100	101–160	> 160	
Pine stands	1174,2 19.9	1544,0 26,1	675,2 11,5	487,6 8,2	392,7 6,6	636,4 10,8	1004,1 16,9	5914,2 100
Spruce stands	332,3 14,2	296,9 12,7	263,4 11,3	176,6 7,6	214,7 9,2	426,3 18,2	621,7 26,7	2332,1 100
Larch stands	0,5 50,0	0,4 40,0	0,1 10,0	–	–	–	–	1 100
Siberian pine stands	0,5 100	–	–	–	–	–	–	0,5 100
Total	1507,5 18,3	1841,3 22,3	938.7 11,4	664,2 8,0	607,4 7,4	1062,7 12,9	1625,8 19,8	8247,8 100

Table 3

Age structure of deciduous forests, 1000 ha / %

Stands (speci-fied according to dominant tree species)	Age, years						Total
	< 10	11–20	21–30	31–40	41–60	> 60	
Birch stands	78,5 8,3	89,3 9,6	283,0 30,1	141,0 15,0	100,3 10,6	247,7 26,4	939,8 100
Aspen stands	3,0 5,2	3,3 5,7	4,9 8,3	2,2 3,8	7,2 12,4	37,4 64,6	58,0 100
Grey alder stands	0,2 0,9	1,5 7,1	4,5 21,1	2,5 11,7	6,6 31,0	6,0 28,2	21,3 100
Common alder stands	–	–	–	–	0,1 20,0	0,4 80,0	0,5 100
Total	81,7 8,0	94,1 9,3	292,4 28,7	145,7 14,3	114,2 11,2	291,5 28,5	1019,6 100

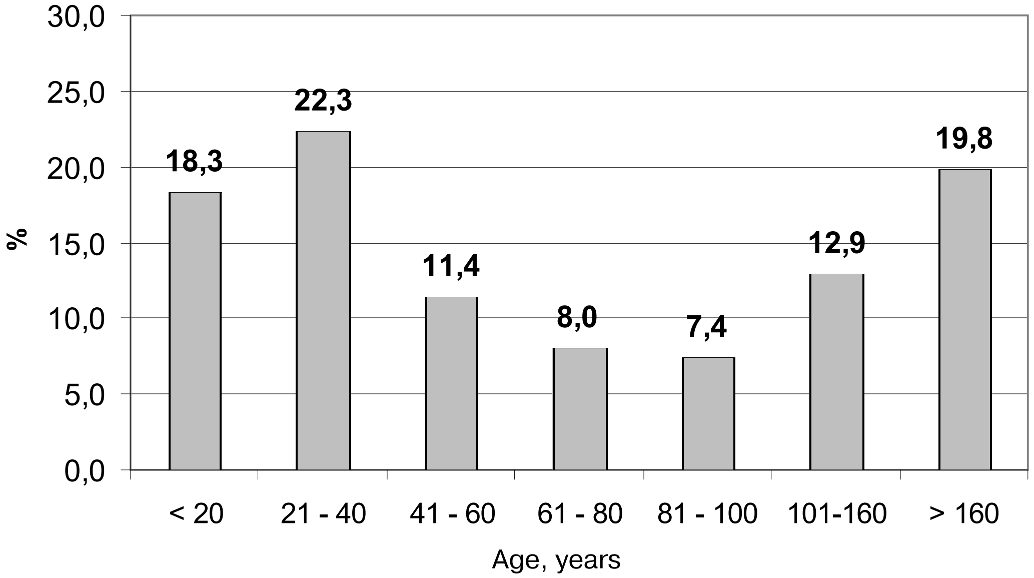

Fig. 14. Age structure of coniferous forests, %

Typological composition of forests (Table 4). Forest types characteristic of the taiga zone of European Russia are widespread. *Lingonberry (Vaccinium)* and *bilberry (Myrtillus)* types are the most common and cover 68% of the total forested area. The north-taiga subzone is dominated by *lingonberry* forests types. These types of pine stands grow on moderately paludified soils with a moderate mineral composition. They are most common on sandy, sandy-pebble and sandy-boulder soil and on paludified plains.

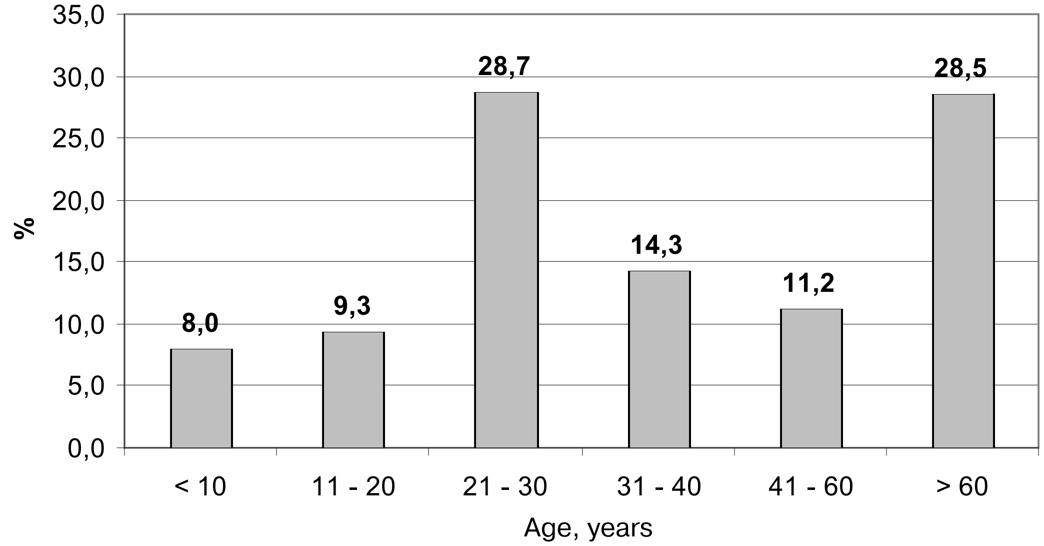

Fig. 15. Age structure of deciduous forests, %

Table 4

Typological structure of forests, %

Habitat types	Northern taiga subzone				Middle taiga subzone				Whole Karelia			
	Stands (specified according to dominand tree species)											
	Pine stands	Spruce stands	Deci-duous	Total	Pine stands	Spruce stands	Deci-duous	Total	Pine stands	Spruce stands	Deci-duous	Total
Rupicolous	9	1	1	2	1	–	–	–	2	–	–	1
Cladonia	4	–	1	3	2	–	–	1	3	–	–	2
Calluna	7	–	3	5	8	1	1	4	7	1	2	5
Vaccinium	35	9	34	30	30	5	18	18	34	7	21	25
Myrtillus	32	56	40	37	33	69	52	32	32	64	56	43
Oxalis	–	–	–	–	1	1	4	1	–	–	3	1
Herb-rich	–	–	2	2	–	1	10	2	–	–	8	1
Herb-rich along brooks	1	8	2	2	–	1	1	1	1	4	1	2
Polytrichum	2	14	6	5	4	15	3	9	3	15	4	6
Herb and sedge-*Sphagnum*	–	2	2	1	2	2	2	2	1	2	2	1
Ledum	10	3	2	8	5	1	–	2	8	2	1	6
Sphagnum	7	7	2	7	14	4	2	8	9	5	2	7

These forest types have a crown density of 0.6–0.7 and fall into the quality classes III–V. The ground cover consists of green moss and dwarf shrubs such as *Vaccinium, Myrtillus* and *Empetrum*, together with a small proportion of herbs.

In *bilberry(Myrtillus)* and *lingonberry (Vaccinium)* forest types spruce phytocenoses dominate on the gentle slopes of hills and in shallow depressions separated by mid to high-podzol soils. The soils consist of morainic sand and sandy loam with intermediate layers of loam. The density of the canopy varies from 0.7 to 0.9 and the quality classes III–V prevail. The ground cover consists of green moss, *bilberry(Myrtillus)*, *lingonberry(Vaccinium)* and herbs.

The above types of birch, aspen and alder forests are dominated by young and medium-aged stands which grew in the wake of felled pine and spruce stands. Oxalis stands are scarce in Karelia. They grow close to *bilberry(Myrtillus*) forests on the richest soils and are highly productive. A large proportion of forested land is occupied by phytocenoses associated with paludified soils. They include *Sphagnum, Ledum* and *Polytrichum* forest types and occupy topographic lows with peat or peat-podzol-gley soils. The productivity of such forest types depends on the extent of groundwater circulation. In the case of circulating water moistening, highly productive forest types are formed in which each storey of vegetation is specifically diverse. Creek spruce stands are one example of this type. If water circulation is poor, less productive forest types such as herb-*Sphagnum* spruce stands are formed. Stagnant water moistening is associated with low productivity forests, e.g. *Sphagnum* pine.

Moisture-deficient (rupicolous, *Cladonia* and *Calluna*) forest types cover only 8% of the total forest area. These types mostly occur in the north-taiga subzone on exposed crystalline rocks, on south-facing esker slopes composed of pebbly sand or on primitive podzols. Only pine grows on such soils. Spruce stands are rare and the only deciduous species encountered are young stands occupying former felling sites.

The woody storey of these phytocenoses is generally of low density (0.4–0.5) and low productivity (quality classes V–Va, b). The ground cover is made up of shrubby lichens mixed with green moss, *Calluna* and other dwarf shrubs.

Productivity and density of stands. The coniferous forests of Karelia (Table 5) most commonly consist of communities of quality classes IV–V with a density of 0.6–0.7 (88.2 and 46.6% of the forested area, respectively) Low density stands (0.3–0.5) account for 28% and high-density stands (0.8–1.0) 18.2%. Sixteen percent of coniferous forests fall into quality classes II and III with 6.8% in classes V–Va, b.

There are some differences in quality class and density distribution between the age groups. Thus, for example, the percentage of phytocenoses of quality class IV is 54.5% among young stands, 37.6% in medium-aged cenoses and 26.7% in mature and overmature stands. Young stands with a density of 0.6–0.7 make up 56.8%, medium-aged forests 52.5% and mature and overmature stands 47.4%. Communities of quality class V account for 31.1% in young stands, 23.8% in medium-aged stands and 53.6% in mature and overmature forests.

Deciduous forests are dominated by cenoses of quality classes II and III. These cover 32.6 and 40.9% of their area respectively. Phytocenoses of quality class IV make up 20.1% and those of classes V and Va, b just 6.4%. Highly dense (at least 0.8) communities constitute 53.7%, medium-density (0.6–0.7) 38% and low-density 8.3%. The average

Table 5

Productivity and density of coniferous forests (1000 ha)

Density	Quality class						
	II and higher	III	IV	V	Va – Vb	Total	%
20–40 years							
0,4	2,3	7,6	75,8	103,1	29,2	218,0	6,5
0,5	15,6	14,1	224,0	264,7	28,1	546,5	16,3
0,6	9,1	54,8	542,9	380,6	10,9	998,3	29,8
0,7	11,1	106,6	574,0	207,8	3,5	903,0	27,0
0,8	10,5	93,8	275,3	61,0	0,8	441,4	13,2
0,9–1,0	11,8	71,8	132,3	25,4	0,3	241,6	7,2
Total	60,4	348,7	1824,3	1042,6	72,8	3348,8	100
%	1,8	10,4	54,5	31,1	2,2	100	
41–80 years							
0,3–0,4	0,8	2,2	12,0	40,9	38,6	94,5	6,0
0,5	2,5	8,5	37,4	77,9	35,3	161,6	10,1
0,6	14,1	44,1	125,9	126,4	12,9	323,4	20,1
0,7	49,5	131,9	234,5	99,6	3,2	518,7	32,4
0,8	47,3	122,4	133,5	27,4	0,6	331,2	20,6
0,9–1,0	32,5	70,9	61,2	8,5	0,4	173,5	10,8
Total	146,7	380,0	604,5	380,7	91,0	1602,9	100
%	9,2	23,7	37,6	23,8	5,7	100	
81–100 years							
0,3–0,4	0,4	1,6	7,0	18,0	12,4	39,4	6,5
0,5	2,1	6,1	17,0	32,9	7,9	66,0	11,0
0,6	8,4	24,8	51,1	51,3	3,5	139,1	23,0
0,7	24,4	57,0	76,6	36,1	1,2	195,3	32,4
0,8	23,6	48,3	44,3	9,3	0,2	125,7	20,2
0,9–1,0	11,1	17,4	12,0	1,4	0,0	41,9	6,9
Total	70,0	155,2	208,0	149,0	25,2	607,4	100
%	11,5	25,5	34,4	24,5	4,1	100	
101 years and over							
0,3–0,4	0,3	1,8	28,1	279,4	285,8	595,4	22,1
0,5	1,2	6,3	84,8	434,3	63,6	590,2	22,0
0,6	3,6	20,0	216,4	470,1	19,6	729,7	27,1
0,7	8,1	49,0	263,7	221,8	3,3	545,9	20,3
0,8	7,0	43,0	101,5	31,8	0,3	183,6	6,8
0,9–1,0	2,6	14,5	22,9	3,8	0,1	43,9	1,6
In total	22,8	143,6	717,4	1441,2	372,7	2688,7	100
%	0,8	5,0	26,7	53,6	13,9	100	
Total							
0,3–0,4	3,8	13,2	122,9	441,4	366,0	947,3	11,5
0,5	21,4	35,0	363,2	809,8	134,9	1364,3	16,5
0,6	35,2	143,7	936,3	1028,4	46,9	2190,5	26,4
0,7	93,1	344,5	1148,8	565,3	11,2	2162,9	26,2
0,8	88,4	307,5	554,6	129,5	1,9	1081,9	13,2
0,9–1,0	58,0	174,6	228,4	39,1	0,8	500,9	6,2
In total	299,9	1018,5	3354,2	3013,5	561,7	8247,8	100
%	3,6	12,4	40,7	35,5	6,8	100	

quality class for the forests of Karelia is IV, 3 (IV, 4 for conifers and IV, 5 for deciduous species). As climatic and soil conditions deteriorate on moving from south to north so the quality also declines. Thus, the predominant quality class in the mid-taiga subzone is IV and in the north-taiga subzone V. Two-thirds of forests are of density 0.5 to 0.7. Highly dense (0.8 and higher) stands account for about 20%.

The forests of Karelia are considered to be healthy. Dead wood and brushwood accumulate as some trees die naturally and others dry out or are damaged by fires, mechanical operations or tapping. The bulk of dead wood displays a low level of invasion by secondary pests as it has been formed a long period of time.

2.1.3. Assessment of the diversity of forest communities

Introduction. In order to determine and assess species and community diversity we need to address the question: what are the limits of diversity? Another important point is the level of natural and dynamic organisation at which diversity is to be assessed. The current state of affairs regarding the assessment of diversity is rather unclear and in need of a methodological basis.

The hierarchic system of the structural and dynamic organisation of forest communities is formed in such a way that biotic diversity increases from one level to the next. For example, there are seldom more than several tens of vascular plant species in a forest biogeocenosis in the taiga zone. A geographic landscape is one order higher in the hierarchic system while a geographic region stands one order above that. The seemingly simple conventional method of assessing floristic and faunistic complexes in administrative and areal units, e.g. provinces, republics and regions) has no real scientific foundation. These units have nothing to do with the organisation of natural systems or location of natural boundaries, distribution areas of animals and plant populations, etc. From this point of view such demarcations are entirely arbitrary.

It should also be noted that biotic diversity in a lower order ecosystem may largely depend on its position with respect to higher order ecosystems. For instance, the number of vascular plants in the ground cover of a common mesic *Myrtillus* pine-dominated denudation-tectonic ridge (selka) in a mid-paludified landscape is about twice as high as in a heavily paludified hilly-ridge landscape of similar genesis and habitats simply because in the former landscape the ground cover is particularly diverse and its microclimatic conditions are favourable. Furthermore, it is impossible to identify and assess the species diversity of most animals and plants at a site level. This can only be done in sufficiently large areas within their natural boundaries.

Methodological basis and methods of study. Studies were carried out in the Republic of Karelia, which includes East Fennoscandia and the adjacent northwestern Russian Plain. The taiga zone of European Russia is the most characteristic landscape of the region (Gromtsev, 2000). The methodological basis was provided by an original classification and a map of landscapes produced using the zonal-typological principle (Volkov et al., 1990, 1995 and others, Table 6, Fig 16). Landscapes were differentiated in terms of genetic types of relief and Quaternary deposits, the extent of paludification and the predominant types of forest habitats (with respect to primeval forests). The landscapes were investigated comprehensively by studying the structure as well as the natural and anthropogenic dynamics of the forest cover including the diversity of forest ecosystems (Gromtsev, 2000; Gromtsev et al., 1995 and others).

Table 6

Classification of landscapes in Karelia (Volkov et al., 1990, 1995 and others)

Predominant Habitats	Degree of paludification		
	High >50%	Medium 20-50%	Low <20%
I. Lacustrine, lacustrine glacial and marine(m) plains:			
Spruce	1/1.5	2/4.0	–
Pine	3/8.5	4/2.0	5/+*
II. Glacial (g) and fluvioglacial (fg) hilly-ridge plains:			
Spruce	–	6/4	–
Pine	7/5.0	8/4.5	9/1.0
III. Glacial accumulation plains with rugged topography:			
Spruce	–	10/2.5	–
Pine	–	11/2.0	–
IV. Denudation-tectonic hilly-ridge plains with complexes of glacial deposits(g) and low mountain topography (lm)			
Spruce	–	12/12.5	–
Pine	13/8.0	14/37.5	–
V. Denudation-tectonic ridge (selga, selkä)			
Spruce	-	15/+	16/1.0
Pine	–	17/2.5	18/1.5
VI. Rock			
Pine	–	19/1.0	20/0.5

Values in the above table indicate the classification of landscape type and the area (% of total) occupied by this type. Thus, for example, 1/ 1.5 indicates that landscape type 1, i.e. spruce growing in lacustrine, lacustrine glacial and marine plains on terrain of over 50% paludification, occupies 1.5% of the area of all landscape types. * less than 0.5%.

Fig. 16. Sketch map of Karelian landscapes

Landscapes provide a convenient tool for determining and comparing biotic diversity at a cenotic level. Under natural conditions the forest cover may be clearly differentiated at several levels. In the case of Karelia the key taxonomic categories or objects are (Gromtsev, 2000):

1) biogeocenosis within a constituent of the genetic form of mesorelief (forest facies). For example, a mesic *Myrtillus* pine stand growing on podzol sandy-loam soil on top of a morainic hill;

2) a complex of biogeocenoses existing in contact with one another and occupying a genetic form of mesorelief (ecosite), e.g. green-moss pine stands growing on underdeveloped bedrock and fully profiled sandy-loam mottled-podzol soils formed on crystalline ridges;

3) a complex consisting of 3–4 forest ecosites which alternate regularly within a territory dominated entirely by the same genetic forms of mesorelief (taiga terrain), e.g. a pine stand growing on an undulating poorly paludified fluvioglacial plain (*Cladonia* and *Vaccinium* stands on sandy podzols and dwarf shrub-*Sphagnum* stands on transitional peat soils, including small open mires and lakes);

4) a complex of several forest terrains in a genetically uniform territory (forest landscape proper), e.g. large spruce stands that grow on loamy sand and loamy soils deposited on limnoglacial plains (general terrain) and alternate locally with isolated closely spaced pine stands on sandy aqueo-glacial hills;

5) a complex of several landscapes similar in their overall spectrum of ecological parameters within different super-landscape units of physico-geographic demarcation, e.g. a large forest growing on loamy-sand and loamy lacustrine and marine sediments in the flat, highly paludified Pribelomorian Depression;

6) a complex of taiga landscapes within a climatic zone (subzone) of a physico-geographic country (landscape region), e.g. the mid-taiga subzone of Fennoscandia.

It should be emphasised once again that such is the structure of the forest cover in the natural state. Its anthropogenic transformation pattern is reflected by a landscape complex of succession lines (Gromtsev, 2000 and others) that are not discussed in this paper.

This well-integrated system of structural units of forest cover arranged in increasing order adequately reflects natural differentiation. Boundaries between the taiga ecosystems of any hierarchic level thus extend along natural boundaries resulting from the interaction of climatic, geomorphological, soil, hydrological and other factors and conditions.

The extent of unequally organised forest ecosystems has been determined. It should be noted that the values given in the present paper indicate the ratios of the areas covered by ecosystems rather than their numerical values because forest communities of a given taxonomic rank vary greatly in area. For instance, landscape areas range from 19 to 1830 thousand hectares (ha) and reflect the heterogeneous landscape structure of the region. The average area covered by forest biogeocenoses in the region is usually several hectares, average contour widths being 110–115 metres. Only in some cases does this figure exceed 10 ha. A forest ecosite incorporates as a rule 2–3 primeval biogeocenoses and covers anything from 10 to over 100 ha, average contour width being about 300 m. A terrain comprises several ecosites and may extend over an area of several thousand hectares including open mires and water bodies. Areas of landscape contours may reach 100 000 ha but do not usually exceed a few tens of thousands of hectares.

The areal dimensions of taiga ecosystems thus increase by about a factor of ten on ascending from one rank to the next. One exception is the transition from ecosite to terrain because mires and water bodies that usually cover large areas are considered to be part of taiga terrains. Correspondingly, the area occupied by taiga ecosystems of this rank increases sharply.

Such an approach makes it possible to determine and assess biotic diversity at any (topological, regional or global) level, clearly relating the distribution of one or other species or community to naturally isolated individual biotopes, areas, territories, etc.

The key problem in our studies was to identify those territories (forest areas) most valuable with respect to the diversity and specificity of forest biota. In order to assess the territories identified, the following criteria were analysed (for each of the 33 landscape types, Table 7):

1) the occurrence in the region or the number of landscape contours;

2) the occurrence of analogues or of similar types of landscape occurring within the same subzone and differing only with respect to a single landscape feature (e.g. the extent of paludification or the predominant primeval forest site type);

3) the area covered in the region.

At the same time, landscape-rank ecosystems were also assessed biogeocenotically according to other criteria such as:

1) the occurrence and distribution of specific types of biogeocenoses (spruce stands and spruce-birch forest-tundra communities growing in low mountain areas, spruce stands on highly paludified sea coasts, mixed cenoses on brown and shungite selka soils and other stands that display irregular phytocenotic structures and original floristic and faunistic complexes);

2) the percentage or proportion of the rarest biogeocenoses (e.g. rupicolous pine stands, *Cladonia* pine stands, Oxalis pine and spruce forests and rupicolous spruce stands that cover not more than 3% of all forested area and occur only in some landscapes). These biogeocenoses occupy extreme growing environments (either the poorest or the most favourable) for the species in question and are, therefore, both structurally and dynamically unusual;

3) Total number of biogeocenosis types determined;

4) the breadth of the typological spectrum of forest biogeocenoses and the quantitative ratio of types of forest community of this rank.

Table 7

Indices, index values and categories distinguished in assessing the distribution and biogeocenotic structure of a landscape type (type of forest land)

N	Indices (for explanations, see text)	Categories of landscape type (forest land type) (rank or numerical values are given in parentheses)				
		Very Rare (5)	Rare(4)	Less Common (3)	Common (2)	General (1)
Index values used to assess landscape type distribution						
1	Occurrence (number of landscape type contours)	1	2	3	4	> 5
2	Occurrence of similar landscape types	No	Only one in same subzone	Only one in other subzone	One in same subzone and one in other subzone	Several in either or both same subzone and other subzone
3	Landscape type area in region	< 0.5	0.5-0.10	1.1–3	3.1–5	> 5.1
Index values used to assess the spectrum and quantitative ratio of biogeocenosis types in landscape type						
1	Presence and distribution of specific biogeocenosis types	General	Typical	Rare	Exception	Absent
2	Percentage of most rare biogeocenosic types (% of forested area)	> 30	21–30	11–20	1–10	< 1
3	Total number of biogeocenosis types determined	> 17	15–17	12–14	9–11	< 9

It should be borne in mind that the biogeocenotic structure of differing landscape types was reduced to primeval types of biogeocenoses because the transformation of the forest cover by human activities varies from one part of the region to another. The primeval type was determined for derivative types of biogeocenoces (Tables 8 and 9).

This approach is comprehensive, involving six separate indices, and bilateral as it considers both biogeocenotic and landscape levels. It may be used to assess the diversity and specificity of forest cenoses in order to differentiate the region according to these aspects. All landscapes were ranked individually with regard to the values of two groups of indices and were split into categories on the basis of total numerical values. In order to avoid errors arising from the uncertainty of particular index values a second assessment was carried out and the same result obtained.

Extensive data collected during a multi-disciplinary assessment of biota on a regional scale (Biodiversity inventories … 1998, 1999, 2000 etc.) was also made use of in our analysis. The results of these studies may be applied by extrapolation to a large part of the taiga zone in European Russia considering the landscape structure of the territory.

The bulk of experimental evidence was provided by data from 50 profiles of a range of landscape types and of total length approximately 250 km.

Results and discussion. Landscape types were split up into five categories on the basis of the results analysed (Fig. 17):

1. Very rare landscapes(12g,19, 20) occupy only about 4% of total area and occupy the highest categories according to the values of two out of three indices analysed (total score 13–15, see Table 7). They all 1) occur in only one place, 2) cover only small areas (about 1–2% of the total area of the region) and 3) have no analogues. Specialised biotic studies conducted in landscapes 12 lm (Paanajärvi National Park area) and 20 (northern Lake Ladoga region) indicate that they are floristically and faunistically unique (Inventory and study of biodiversity …1998, 2000).

2. Rare landcapes (5, 7fg, 11, 15, 17) cover 6% of the region. These occupy the highest categories with respect to the values of 1–2 indices (total score 10–12). They usually cover small areas (0.5–3% of the total region) and have only one analogue either in the same subzone or in other subzone. Specialised studies of biotic diversity were only conducted in landscape 17 (Zaonezhye Peninsula). Species and cenotic diversity was found to be very high (Biodiversity inventories ..., 2000).

It is safe to assume that other landscapes of this category also contain highly diverse biota. One example is the large crystalline Windy Belt ridge located in the easternmost part of the crystalline Baltic (Fennoscandian) shield (landscape 15). This cuts across the Russian plain and extends eastwards over a large distance as far as the province of Arkhangelsk. Thus, a well-defined topological boundary exists between these physico-geographic countries which differ from one another markedly in their biota-forming conditions.

3. Less common landscapes (1m, 3m, 9fg, 16, 18) cover 8% of the region. They are considered original chiefly because they occupy a relatively small area and are represented by only 2–3 contours. In none of the indices do they occupy the lowest or the highest positions (total numerical values are 8–11). It is only on the White Sea coast that stud-

Table 8

Biogeocenotic structure of primeval forests in various types of mid-taiga landscape (based on landscape profile data)

Type of biogeocenosis *	Representativeness of type of biogeocenosis (% of forested area) in various types of landscape (for numerical values see Table 6).														
	2	3	4	5	6g	7fg	8fg	9fg	10	12g	13	14g	16	17	20
Pinetum saxatilis	0**	0	0	0	0	0	0	0	0	5	0	0	10	1	25
Pn.cladinosum	0	5	0	5	0	1	0	0	0	0	0	6	0	0	0
Pn. vacciniosum rupestrum	0	0	0	0	0	0	0	0	0	4	0	2	0	6	23
Pn. vacciniosum	1	4	8	34	2	44	25	11	0	0	37	32	0	0	0
Pn. myrtillosum rupestrum	0	0	0	0	0	0	0	0	0	1	0	0	8	15	10
Pn. myrtillosum	6	16	12	27	21	14	50	22	10	13	19	17	12	50	11
Pn. myrtillosum humidosum	0	17	12	8	0	2	3	0	0	0	6	6	0	1	2
Pn. myrtilloso-sphagnosum	0	0	1	0	0	0	0	35	3	1	0	0	8	4	4
Pn. uliginio-fruticulosum	0	4	3	0	0	0	1	0	0	2	4	3	0	2	1
Pn. herboso-, equiseto-sphagnosum	11	0	0	6	1	0	0	0	0	2	0	1	0	1	3
Pn.fruticuloso-sphagnosum	9	17	24	8	3	31	16	0	1	5	13	17	0	4	9
Pn..caricoso-sphagnosum	3	6	0	0	1	0	0	0	0	5	8	6	3	0	1
Pineta in total	**30**	**69**	**60**	**88**	**28**	**92**	**95**	**68**	**14**	**38**	**87**	**90**	**41**	**84**	**89**
Piceetum myrtillosum rupestrum	0	0	0	0	0	0	0	0	0	8	0	1	7	1	1
Pc. myrtillosum	56	18	15	10	37	0	3	16	58	26	3	2	12	8	5
Pc. myrtillosum humidosum	7	9	13	0	10	0	0	0	9	10	5	0	14	1	1
Pc. oxalidosum	0	1	5	0	3	0	0	1	15	5	0	0	8	0	0
Pc. myrtilloso-sphagnosum	5	2	1	2	7	0	1	0	1	6	1	3	8	0	0
Pc. fontinale	0	1	1	0	1	3	0	2	2	1	0	0	2	5	3
Pc. herboso-, equiseto-sphagnosum	2	0	4	0	14	2	1	13	1	6	3	4	5	1	1
Pc. caricoso- sphagnosum	0	0	1	0	0	3	0	0	0	0	1	0	3	0	0
Piceeta in total	**70**	**31**	**40**	**12**	**72**	**8**	**5**	**32**	**86**	**62**	**13**	**10**	**59**	**16**	**11**

* For a list of biogeocenosis types in English see supplement.

** Not identified in landscape profile.

ies with a special emphasis on biotic diversity were carried out (landscapes 1m, 3m). These showed that both species and communities occurring in the study area possess distinctive patterns of diversity (Inventory and study of biodiversity … 1998).

Based on preliminary data (Gromtsev et al., 1995), landscapes 16 and 18 of the 'selka' group are assumed to be similar in biotic diversity to landscape 17 (see rare landscape category).

4. Common landscapes (2, 3, 4, 6g, 7g, 8fg, 8g, 10, 13, 13g, 14) cover 41% of the region. Being of widespread occurrence they score the lowest values in 1–2 indices analysed (total score 4–7). They display a normal biotic diversity except for some fragments of territories ranking as sub-landscape units (terrains and ecosites). Thus for example, a very high vascular plant diversity is found in large-scale tectonic faults with spruce stands growing on rich soils with circulating moistening.

5. General landscapes (12g, 14g). These two types of landscape are similar in biotic diversity to the above. However, covering 41% of the region, they form a category of their own (total score 3, occupying only the lowest positions). General landscapes are the most common for both the mid-taiga and north-taiga subzones.

Only three of the above landscape types were identified on the basis of biogeocenotic diversity (see Tables 8 and 9):

1.Rare landscapes (3m, 12lm, 19, 20) occupy 7% of the region (total score 10–12, the lowest values of the indices analysed are not included). They exhibit a high percentage of rare types as well as structurally and dynamically specific forest communities, e.g. rupicolous pine stands growing on the White Sea and Lake Ladoga shores (3m, 19, 20). 20–50% of these areas are taken up by rare landscapes (an unprecedentedly high figure for Karelia) where woodlands are formed on large crystalline domes. This category also includes a low-mountain landscape (12lm) with unique thin *Myrtillus* spruce stands and forest-tundra communities rimming large crystalline hills with unique floristic complexes.

2. Original landscapes (1m, 9fg, 12g, 14g, 15, 16, 17, 18) cover 49% of the region (total score 7–9). They display a relatively broad biogeocenotic spectrum (e.g. landscapes 12g and 14g include almost all types of forest communities except for coastal and low-mountain types) or contain a substantial contribution of original forest types such as 1) highly productive mixed *Myrtillus* and rupicolous *Myrtillus* pine and spruce stands with enriched floristic composition growing on rich soils formed on ultramafic and mafic rocks (landscapes 16 and 17); 2) thin coastal spruce stands with meadow patches on saline marsh soils containing numerous rare vascular plant species, etc.

3. Common landscapes (2, 3, 4, 5, 6g, 7g, 7fg, 8fg, 10, 11, 13, 13g, 14) occupy 44% of the region (total score 4–6 with 1–2 lowest positions). These are the most common in terms of both the spectrum and quantitative ratio of biogeocenosis types.

Based on the above criteria, none of the landscape types qualified as 'very rare' or 'general'. The biogeocenotic structure of these landscape categories has already been described in detail in previous publications (Biodiversity inventories … 1998, 1999, 2000; Gromtsev, 2000 and others).

Table 9

Biogeocenotic structure of primeval forests in various types of north-taiga landscape (based on landscape profile data)

Type of biogeocenosis	Representativeness of type of biogeocenosis (in % of forested area) on various types of landscape (for numerical values see Table 1)											
	1m	3m	3	4	8fg	12g	12lm	13g	14g	14	18	19
Pn. saxatilis	6	21	0	0	0	0	0	0	1	5	0	50
Pn.cladinosum	0	0	8	22	20	0	0	0	0	0	0	0
Pn. vacciniosum rupestrum	0	3	7	8	3	0	10	7	2	12	6	5
Pn. vacciniosum	2	5	43	34	56	2	0	5	6	33	35	0
Pn. myrtillosum rupestrum	0	0	0	0	0	0	0	7	1	2	7	8
Pn. myrtillosum	0	2	0	0	6	26	5	30	35	9	28	0
Pn. myrtillosum humidosum	0	5	0	0	0	0	0	3	3	2	0	0
Pn. myrtilloso-sphagnosum	4	0	0	0	0	0	0	3	3	0	0	0
Pn. uliginio-fruticulosum	8	15	8	6	2	0	0	1	0	17	1	8
Pn.fruticuloso-sphagnosum	33	44	34	18	4	11	0	8	14	0	4	13
Pn.caricoso-sphagnosum	5	2	0	0	9	5	0	2	8	20	2	3
Pineta (Pn) in total	**58**	**97**	**100**	**88**	**100**	**44**	**15**	**66**	**73**	**100**	**83**	**87**
Pc. myrtillosum rupestrum	4	0	0	0	0	2	26	0	1	0	1	8
Pc. myrtillosum	0	0	0	0	0	50	47	25	9	0	8	0
Pc. myrtillosum humidosum	28	0	0	0	0	0	9	4	7	0	0	0
Pc. myrtilloso- sphagnosum	4	0	0	0	0	0	1	3	4	0	0	3
Pc. fontinale	0	2	0	6	0	1	0	2	3	0	6	1
Pc. herboso-, equiseto-sphagnosum	6	1	0	4	0	1	0	0	1	0	2	1
Pc. fruticuloso-sphagnosum	0	0	0	2	0	2	2	0	2	0	0	0
Piceeta (Pc) in total	**42**	**3**	**0**	**12**	**0**	**56**	**85**	**34**	**27**	**0**	**17**	**13**

Conclusion. The results presented were obtained in the first stage of a landscape-based study of the diversity of taiga ecosystems. In the region under study they can be used to differentiate forest areas of the order of 100 000 ha in this aspect. The most valuable woodlands were identified where study of species and cenotic levels is desirable. The data obtained by specialised assessment of biotic diversity shows that this approach is correct (Biodiversity inventories … 1998, 1999, 2000 et al.). The characteristics of the region can be analysed in the same way at a sub-landscape level (ecosites that cover up to 1 000 ha and terrains that occupy 1 000–10 000 ha).

On the other hand, the classification proposed provides a permanent systemic basis for conducting such studies in the region. It may be used in order to design a representative network of experimental areas covering the entire territory where the study of biodiversity is considered desirable. Using the ratios of the different types of landscape and sub-landscape units, data obtained may be extrapolated for any part of the region. This approach is methodologically applicable to any taiga region.

In accordance with the principle of landscape representativeness, a regional system for a network of protected areas containing primeval forests and of great value in terms of biodiversity has been proposed (Gromtsev, 2000 and others).

Supplement

Types of forest biogeocenosis

(Latin)	(English)
1. *Pinetum. saxatilis*	*Rupicolous pine stand*
2. *Pn. cladinosa*	*Cladonia pine stand*
3. *Pn. vacciniosum rupestrum*	*Rupicolous Vaccinium pine stand*
4. *Pn. vacciniosum*	*Vaccinium pine stand*
5. *Pn. myrtillosum rupestrum*	*Rupicolous Myrtillus pine stand*
6. *Pn. myrtillosum*	*Myrtillus pine stand*
7. *Pn. oxalidosum*	*Oxalis pine stand*
8. *Pn. myrtillosum humidosum*	*Humid Myrtillus pine stand*
9. *Pn. myrtilloso-sphagnosum*	*Myrtillus-Sphagnum pine stand*
10. *Pn. uliginio-fruticulosum*	*Mire-dwarf shrub pine stand*
11. *Pn. fruticuloso-sphagnosum*	*Dwarf shrub-Sphagnum pine stand*
12. *Pn. caricoso-sphagnosum*	*Sedge-Sphagnum pine stand*

13. *Piceetum myrtillosum rupestrum*	*Rupicolous Myrtillus spruce stand*
14. *Pc. myrtillosum*	*Myrtillus spruce stand*
15. *Pc. oxalidosum*	*Oxalis spruce stand*
16. *Pc. myrtillosum humidosum*	*Humid Myrtillus spruce stand*
17. *Pc. myrtilloso-sphagnosum*	*Myrtillus-Sphagnum spruce stand*
18. *Pc. fontinale*	*Creek (ravine) spruce stand*
19. *Pc. herboso-, equiseto-sphagnosum*	*Grass-, horsetail-Sphagnum*
20. *Pc. fruticuloso-sphagnosum*	*Dwarf shrub-Sphagnum*

2.1.4. Landscape models of the primeval forests

Introduction. The basic criterion used for evaluating a system of strictly protected areas is the representativeness of its landscapes. This is because the structure of biota is dependent on landscape characteristics such as the nature and genesis of relief, rock composition, the composition and thickness of Quaternary deposits, the extent and pattern of paludification, the characteristics of its hydrographic network, the composition of the soil cover and microclimatic conditions present, etc. In an ideal case each type of landscape-ranking taiga ecosystem would be conserved.

The first stands to be protected in taiga areas nowadays are primeval forests. As a result of large-scale commercial felling these have become greatly diminished in size and occur only as fragments. *The westernmost fragments of primeval forest in the taiga zone of Eurasia and the last relatively large fragments in Fennoscandia are to be found in Karelia.* Of particular importance are several landscape models of primeval forest which differ considerably from one another with respect to all parameters of natural structural-dynamic organisation including biotic diversity (Fig. 18).

Spruce forests in a low-mountain landscape (near Lake Paanajärvi, Paanajärvi National Park, area N «A', see fig. 18). Spruce stands account for about 85% of the forested area with rupicolous *Myrtillus* and fresh *Myrtillus* spruce stands predominating. Forest communities were formed in a large burned-over area at least 300-–350 years ago and passed through a coeval stand stage. The multi-age structure of the stand is presently developing. The average age of stands varies from 160 to 200 years. The average age refers to the generation predominating the stand in terms of timber reserves. However, the age of all trees in the upper storey actually covers a considerable range, i.e. from 80 to over 270 years (the maximum age reported so far on mineral soils). This shows that the formation of the stands of differing age structures, a standard indicator of climax forest communities, is gradually coming to an end. The forests are poorly productive (average quality class is V, 6 and wood reserves at the age of 120–140 years are 115 m^3/ha.

These spruce stands have remained more or less untouched by selective felling. Such spruce communities in Karelia, including spruce-birch forest-tundra communities, are very rare. They grow in severe conditions on the thin soils of low mountains in the coldest part of Karelia. Their flora is highly characteristic and they are highly sensitive to human activities (from here onwards the author uses the term 'sensitive' to mean those stands susceptible to atmospheric pollution, capable of regenerating naturally after clear felling and resistant to recreational stress.

Pine forests in a rupicolous north-taiga landscape (northern part of the Karelian White Sea coast, area N «B', see fig. 18). Pine stands make up about 90% of the forested area. Rupicolous and green-moss rupicolous pine stands predominate (60 and 15% of the pine forest area respectively). The age structure of the pine stands is characterised by 2–3 indistinct pine generations with ages of approximately 100, 200 and 300 years. This structure results from the periodic elimination of individual trees and their biogroups by forest fires. Gaps formed by fires are then filled by individual pines or groups of pine undergrowth. A pine generation aged 250 to 350 years is prevalent in terms of wood reserves. These forests are of low productivity (average quality class is Va.5 and wood reserves at the age of 120–140 years are 65 ^{3}/ha). The bulk of pine stands growing on mineral soils were affected by low to moderate intensity selective felling over 50 years ago. During the intervening period the natural structure of the stands has been more or less restored. As a result of felling the proportion of 200 to 300 year old trees has decreased. This is a very rare type of woodland and grows under extreme conditions on large rocky domes with almost completely exposed crystalline basement surfaces in one of the coldest areas of Karelia. Its flora is poor in terms of species composition and it is sensitive to human activities.

Spruce forests in a highly paludified sea plain landscape (northern part of the Karelian White Sea coast, area N «C, see fig. 18). Predominantly open paludified pine stands cover about 60% of the forested area. However, spruce stands prevail on 80% of drained land. This is a fundamental environment–forming forest type. Spruce forests mostly (70%) comprise humid *Myrtillus* stands (in the initial stages of paludification with a thick coarse-humus litter partly transformed into peat). This woodland has avoided the effects fires for at least 400–500 years. The oldest spruce trees growing on mineral soils are about 300 years of age. The spruce stands evolving on mineral soils are of low density (0.45–0.55) and occur as islands in large open mires and within thin pine stands on peat deposits. These forests are poorly productive (average quality class is Va.5 and the wood reserves of 120 to 140 year old trees are 70 m^3/ha).

These spruce forests consist of unique virgin stands bearing no signs of felling. They grow on a highly paludified flat sea plain in one of the coldest areas of Karelia. Their coastal flora and fauna are highly characteristic. They are highly sensitive to human activities.

Pine forests in a north-taiga denudation-tectonic landscape (west of Lake Kuito (Kuittijärvi), mostly within the Kostomuksha Strict Natural Reserve and the proposed Kalevala National Park, area N «D', see fig. 18). Pine stands cover about 85% of the forested area. Extensive stands of pine with spruce growing mostly along the hydrographic network are common.

The forest communities occurring in this territory are representative of almost all the forest types known in Karelia. Generally speaking, this territory displays a *topo-ecological succession* of forest communities highly typical of East Fennoscandia. Almost all types of forest biogeocenoses succeed one another in various combinations from hill and ridge tops to the central parts of large mires. Rupicolous pine stands occupy 1% of the forested area and are restricted to occasional exposed scarps in the crystalline Baltic shield. On slopes they give way to fresh *Myrtillus* pine stands (35%) growing on sandy loam podzols. Fresh *Myrtillus* spruce stands (10%) are common on the lower parts of hills and ridges where they usually occur together with ravine spruce stands (3%) on rills of discharge. On mineral soils forest communities of dwarf shrub-Sphagnum pine stands (15%) are common on peat soils rimming open mires on plains, etc.

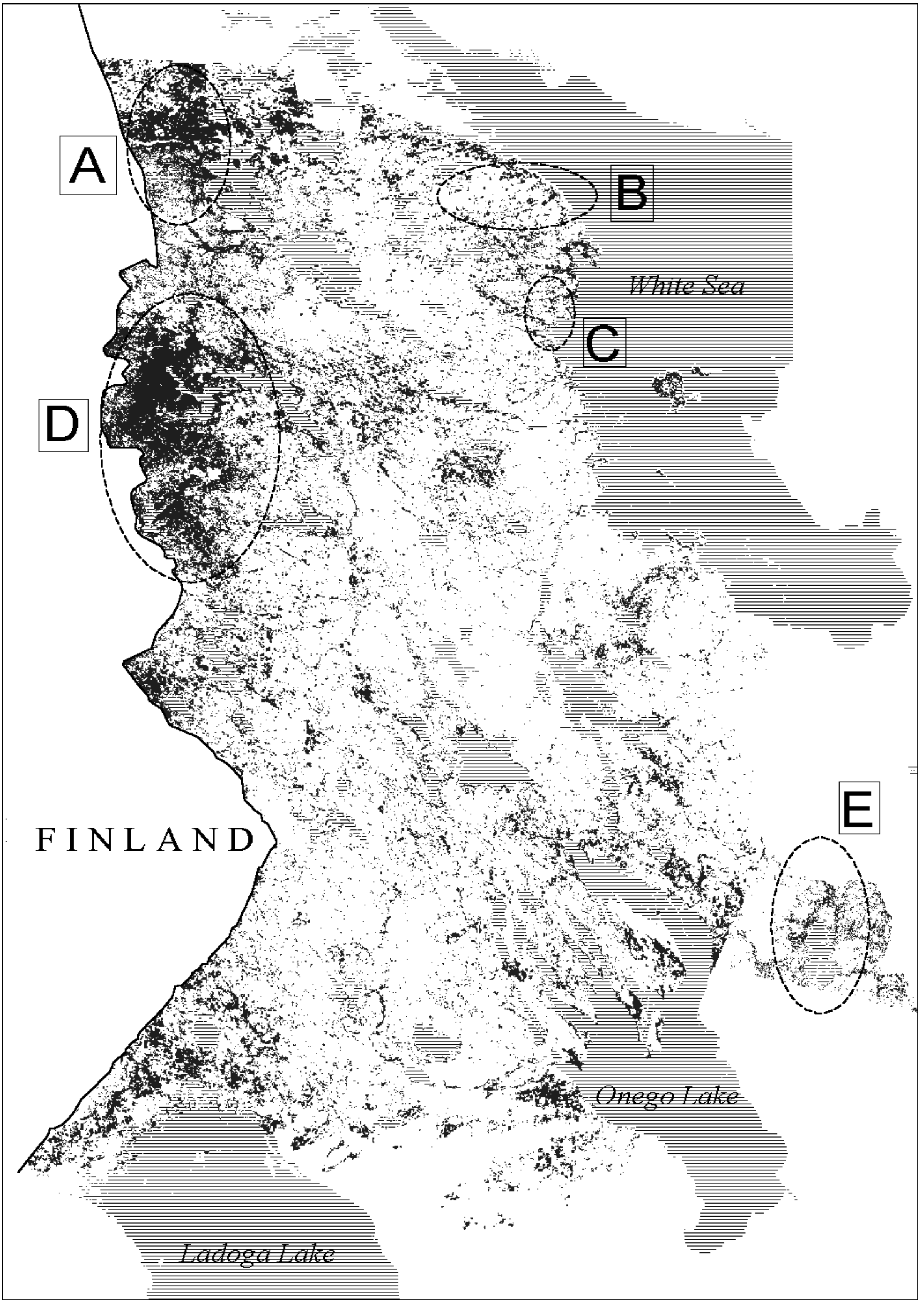

Fig. 18. Highly dense coniferous forests over 120 years in Karelia. Satellite scanning survey data, 2000. Image processed by P. Litinsky. Image boundaries are shown by a dotted line. Letters indicate areas with the last large fragments of primeval forest (see text).

Phytocenotically, these forest communities are highly typical of the north-taiga subzone of East Fennoscandia. The composition of their stands (predominance of conifers) and that of the ground cover (occurrence of common plant species) are typical. Lush spruce undergrowth or a secondary spruce storey exists under the canopy of about half of rupicolous *Myrtillus* and fresh pine stands. In these stands pine does not regenerate and is being gradually ousted by spruce. In nature a stable dynamic equilibrium between pine and spruce formations is maintained by periodic fires.

Age of forests. Stands growing on most mineral soils vary in age from 120 to 160 years. The maximum age of individual trees growing on the periphery of paludified habitats is estimated at 450 years. It is difficult to determine this most important of parameters in the oldest trees because the cores of their trunks are affected by rot. The age structure of stands varies considerably from one habitat type to another. For example, rupicolous pine stands commonly contain at least 2–3 tree generations with ages ranging from 80 to over 300 years and wood reserves varying substantially. Fresh *Myrtillus* pine stands are generally coeval (120 to 140 years) but individual pine trees may be over 300 years old. In ravine spruce stands trees may vary markedly in age and the transition between the age groups is smooth. The greatest age reported for ravine spruce stands is 270 years. However, 160 to 200 year old trees predominate. The forests discussed are highly productive (average quality class is IV.5 and wood reserves at the age of 120 to 140 years are 140 cubic metres/ha).

Generally speaking, the territory contains a complete natural spectrum of forest communities ranging from open plant communities growing in burned-over areas to climax spruce stands evolving in ravine habitats that can hardly have been affected by fires.

Forest growth conditions are fairly uniform and favourable to both pine and spruce over most of the area. Since spruce prefers the shade the area covered by spruce stands increases by virtue of a secondary spruce storey penetrating the upper pine canopy. Rupicolous, sedge-Sphagnum and other types of habitats associated with extreme growing conditions are the exception rather than the rule. However, the present-day areal distribution of pine and spruce stands is basically a consequence of the pattern of forest fires over the past millennium.

Most profoundly affected by forest fires are rupicolous pine stands (4 fires in the past 170 years). In *Vaccinium* pine stands some individual dead standing trees bear no less than seven non-coeval fire scars. In creek, ravine, grass, and horsetail-*Sphagnum* types of spruce stands, traces of fire are observed only at the periphery. Dating of fire scars on trees has shown that fires broke out in rupicolous *Vaccinium* and fresh *Vacciniu*m pine stands growing on mineral soils about 220, 130, 100 and 60 years ago. Based on the results of stratigraphic analysis of peat deposits the oldest fires occurred in this area at least 3000 years ago. Over the past millennium fires occurred about once every hundred years and spread over most mineral soils. A greater number of fires occurred over the past few centuries presumably due to human activities.

Modern forest communities thus represent different stages of pyrogenic succession ranging from pioneer plant groups occurring in open burned-over areas to relatively stable 300 year old stands with at least two to three generations of trees that have survived a number of fires.

At least a half of the forests growing on mineral soils have been subjected to selective felling although this has generally been of low intensity. This has not produce any substantial effect on the structure of communities but has resulted in a higher percentage of spruce in areas where pine was felled. These are the largest well preserved fire-generated primeval pine taiga forests in Fennoscandia as well as being the westernmost in Europe. The forest communities evolving in this territory are highly typical of the north-taiga subzone of East Fennoscandia.

Coniferous forests in mid-taiga mostly on morainic landscapes (near Lake Vodlozero, mostly in the southern part of Vodlozero National Park, area N «E', see fig. 18). Pine and spruce stands occur in such forests in the ratio of approximately 1:4. Primeval stands were formed on mineral soils about 350–400 years ago after large-scale fires which devastated large adjacent territories including some areas in the districts of Arkhangelsk and Vologda. When free from external disturbance forest communities evolve in paludified habitats over long periods of time.

Pine forests. Myrtillus pine stands and dwarf shrub-*Sphagnum* pine stands occur in approximately equal proportions. Stands growing on mineral soils are coeval as they evolved in an open burned-over area and the first generation of trees is still intact. The average age of pines is about 300 years. Spruce undergrowth and fragments of a secondary spruce storey are generally widespread enough for gradual species succession to occur after 100–150 years.

In paludified habitats there generally occur two or three age groups of pine trees. The age of individual trees varies substantially as these communities have long escaped the effects of external factors, excepting that of wind.

Pine stands covered at least a quarter of the forested area. By now their proportion in territories undisturbed by clear felling has fallen markedly as a result of repeated selective felling. Pine communities display a very broad typological spectrum. Pine stands evolved in all types of forest habitats ranging from the driest oligotrophic habitats, e.g. small fragments of *Cladonia* pine stands growing along open mires, to the wettest oligotrophic environments, e.g. sedge-*Sphagnum* pine stands. However, over most of the territory pine forests are dominated by fresh *Myrtillu*s stands (about 70%).

Both the structure and patterns of succession of primeval pine stands are highly diverse. These were affected by fire to a far greater extent than were spruce stands. Coeval pine stands were commonly formed on open burnt-over areas. On light sand and loamy sand soils they were periodically damaged by fires. Some burnt trees died and the resulting gaps were filled by groups of pine undergrowth. As a result pine phytocenoses containing two or three generations were formed. In paludified habitats rarely affected by fires old trees that died out were gradually replaced, thus giving rise to stands of mixed age with no particular generation dominating the upper storey.

Luxuriant spruce undergrowth and a secondary spruce storey were formed in pine stands that penetrated spruce forests. Three hundred years after pine started to regenerate in burned-over areas spruce gradually began to prevail in the first storey and eventually pine stands were transformed into spruce stands.

In the absence of fires over most of this territory pine forests were gradually replaced by spruce stands, except in paludified oligotrophic habitats with extreme forest-growing conditions where this process is indefinitely long.

Spruce forests are generally dominated by *Myrtillus* spruce stands (about 75%). Few trees in this forest type are older than 300 years. Preliminary data suggests that the first spruce generation to form in burnt-over areas under a birch canopy has by now completely disintegrated. Mixed aged spruce communities are now evolving.

Forest communities are partially disintegrating and rejuvenating according to what may be described as a gap-mosaic pattern. Gaps are formed by storms which may be powerful enough to fell individual trees and even groups of trees. Such patches vary in size from a few square metres to over half a hectare. Such gaps are generally filled by aspen with spruce as undergrowth. The aspen storey then disintegrates and spruce begins to dominate (a coeval area of spruce is formed). The subsequent partial disintegration of the spruce biogroup is accompanied by the formation of a new generation in gaps and so on.

Gap-mosaic may vary from recently formed open sites with fallen aspen trunks to 120 year old aspen stands with a secondary spruce storey penetrating the upper canopy. *Myrtillu*s spruce stands of quality class III prevail.

This particular territory includes a variety of paludified habitats which vary substantially in peat thickness, extent of flowage, size and outline of area occupied, etc. In monodominant spruce forests such habitats are usually occupied by spruce stands. These are protected from even large-scale fires and may thus exist in stable dynamic equilibrium for thousands of years. Only global climatic variations can affect them.

Paludified spruce stands contain a number of tree generations. Indeed, specimens of all ages ranging from seedlings on fallen and decaying trunks to 330 year old individuals growing on mineral micro-elevations may be found. A high degree of vertical differentiation and horizontal mosaicity is typical of these forest communities. Individual birches commonly occur in the upper storey, alder and birch being present in the undergrowth. Productivity usually corresponds to quality class V.

Under natural conditions forest-forming processes began in large open burnt-over areas rapidly overgrown by birch and to some extent aspen. The developing canopy of deciduous stands was gradually penetrated by spruce originating from paludified spruce forests that had survived fires. Thus deciduous stands with undergrowth followed by a secondary spruce storey were formed. Between 100 and 120 years later spruce began to dominate in the upper storey and after the dying-out of the shorter-lived deciduous species coeval spruce stands became established. As the first spruce generation disintegrated a second generation of spruce began to fill the gaps and so forth leading to the formation of stands of mixed age. These existed in a climax state (i.e. in a relatively stable dynamic equilibrium) until the next catastrophic fire broke out. The formation of mixed age climax spruce forest takes about 500 years.

The pine and spruce stands that occur in the western part of the mid-taiga subzone are very common in type and contain highly characteristic flora and fauna. They are fairly resistant to human activities. Spruce stands regenerate through a deciduous community stage.

Conclusion. Model forests play a key role in the conservation of the full spectrum of natural diversity of the taiga zone. Primeval forests have persisted as small isolated fragments elsewhere in Karelia, e.g. in the Kivach Strict Nature Reserve, where they cover 10 000 ha in a mid-taiga tectonic ridge (selka) landscape. These forests stand out against large secondary coniferous-deciduous forests formed on former felling sites. Woodlands transformed by human activities, e.g. the forest communities in the landscapes of the Zaonezhye Peninsula and along the northern shore of Lake Ladoga, display a highly diverse flora and fauna. In spite of large-scale agricultural development and forest management these may also serve as models, their value depending on the degree of rare or otherwise unique characteristics involved.

Based on the representativeness of landscapes in protected areas, we believe that at the very least *all major landscape models (standards) of primeval taiga* must be conserved. In other words, an areal system of taiga fragments consisting of contrasting types of geographic landscapes is required. Several basic variants are proposed tentatively for the western part of Russian taiga zone:

– 'red' taiga, understood as pine forests generated on pyrogenic aqueoglacial landscapes;
– 'black' taiga, consisting of spruce stands growing in low-mountain or morainic landscapes;
– 'light' taiga, composed of mixed spruce-pine forests evolving in selka landscapes, etc.

In order to form a network of protected areas forests should be divided on the basis of landscape zoning into a number of major categories, namely, 1) main stands that occupy most of the forested area; 2) rare stands covering small areas in some parts of the region; and 3) unique stands known only at one locality. These categories may be used as basic models (standards) reflecting the native diversity of forests.

2.2 Mires

2.2.1. Mire vegetation

Introduction. Mire ecosystems are structurally complex and they were studied on 3 to 7 organisation levels (Cajander, 1913; Galkina, 1946; Lopatin, 1954; Masing, 1960, 1982; Moen, 1990 and others). Four basic structural categories, namely, **mire complex systems, mire complexes (massifs), mire sites and mire communities (cenoses),**

form the basis for describing the diversity of mire ecosystems in any large region. Research methods and principles of classification vary from level to level.

The Republic of Karelia is a highly paludified region located in the boreal zone. Mire ecosystems cover one third of its territory. The geological, geomorphological and climatic conditions of Karelia are responsible for the diversity of vegetation, genesis and stratigraphy of its mires. Karelian mires have been studied thoroughly and have been described in over a thousand publications (Yelina et al., 1984, Methods …, 1991). In the present paper the diversity of mire ecosystems is characterised according to number of structural levels although emphasis is placed on the mire community level which is of primary importance for assessing the diversity of ecosystems in any region. The vascular plant flora of Karelian mires has been analysed earlier (Kuznetsov, 1989).

Typology of mire massifs and mire complex systems. The criteria used to distinguish between types of **mire massifs** are vegetation, hydrology and stratigraphy. On this basis a classification containing several types of Karelian mire massifs has been proposed (Galkina, 1959; Yurkovskaya, 1975). The classification of mire massifs in the European part of the former USSR was drawn up according to floristic and geographic criteria. It includes twenty-eight geographic types of mire massifs (Yurkovskaya, 1980), thirteen of which may be found in Karelia. Mire massif types in Russia were defined as part of the production of a vegetation map of Europe (Rybnicek & Yurkovskaya, 1995). Of twenty-two types occurring in Europe nine are found in Karelia. Four types occur at the boundaries of their distribution areas (Fig.19) and the lichen-rich subtype of *Sphagnum fuscum* raised bog of the White Sea Coastal region occurs chiefly in Karelia. Some of the types proposed earlier in the former USSR (Yurkovskaya, 1980) are regarded as variants of larger European types.

Most mire massifs in this region form mire complex systems. The main types of Karelian mire complex systems have already been described (Galkina, 1959; Yurkovskaya, 1995). The typology of mire systems was first developed in 1968 during the production of a mire vegetation map of Karelia (Yurkovskaya, 1968). There are few publications outside Russia which analyse the structure and genesis of mire complex systems.

Typology of mire sites. Mire researchers outside Russia study the structure of mire ecosystems mostly at the level of mire sites. Mire sites are distinguished and classified on the basis of floristic, ecological and hydrological criteria. There are detailed classifications of mire sites in Finland (Ruuhijärvi, 1960; Eurola et al., 1984) and Canada (Racey et al., 1996). A comprehensive classification of mire vegetation has also been developed for North Europe (Påhlsson, 1994). According to some European and North American classifications mire sites are identified in terms of plant communities (associations). However, many mire types have a well-developed microrelief and occur as a complex of several associations (Eurola et al., 1984; Jeglum, 1991).

According to Russian mire terminology mire sites are commonly called facies (Lopatin, 1954). In Russia facies are classified with respect to vegetation characteristics and nutrient content. Simple and complex (e.g. ridge-hollow, string-flark) groups of facies are always distinguished. Several classifications of mire facies have been developed for some parts of Karelia but there is still no classification for the whole of Karelia.

Methods of classifying vegetation. The level preceding that of the mire site in the structural study of mire ecosystems is the **mire community**. Mire communities commonly cover areas of tens to hundreds of square metres determined according to the size of edificators of mire communities, natural succession on mires and the development of microrelief.

The diversity of vegetation at a cenotic level (β-diversity) and its conservation in any given region are based on the classifications of communities. Methods of classifying vegetation have been discussed by phytocenologists for over a hundred years. Some methods and principles of classification of communities have been developed. The main principles relate to dominant, floristic and topological-ecological features (Alexandrova, 1969; Mirkin, 1985). Each method has its own syntactic units and criteria for identifying them. The lowest units in most classifications are associations, their ranges varying substantially.

All the above methods are also used to classify mire communities in Russia and Europe (Boch & Smagin, 1993; Dierssen, 1982; Moen, 1990). Mire vegetation has been studied most thoroughly in Northwest Russia and the countries of Scandinavia. Some classifications have been developed according to a variety of methods (Osvald, 1923; Bogdanovskaya-Guienef, 1928; Paasio, 1941; Nordhagen, 1943 and others). Classifications presented in some publications (Zinzerling, 1938; Yurkovskaya, 1959, 1992; Kuznetsov, 1991 and others) are arrived by different methods and do not account for the full diversity of Karelian mire communities.

Floristic classification of mire vegetation of Karelia. Over the past fifteen years analysis of all available data concerning Karelian mire vegetation has been carried out with a view to improving its classification. A data bank of over 5 000 geobotanical descriptions (releves) has been compiled. Initially it was decided to develop a classification employing the floristic method widely used in Central Europe and lately in Russia to classify mire vegetation (Rybnićek, 1985; Boch & Smagin, 1993). A preliminary floristic classification of mire vegetation was produced which consisted of 36 associations belonging to 12 alliances, 9 orders and 5 classes. The classification and the distribution of each association identified in nature reserves and national parks (both existing and proposed) lying along the Russian-Finnish border has recently been published (Kuznetsov et al., 1998; Kuznetsov et al., 2000). To classify mire communities floristically a complex procedure for identifying and validating unequally ranking syntaxa is used. In order to distinguish syntaxa geobotanical data from adjacent areas (descriptive tables) must be compared and the floristic and climatic patterns of the study regions must be considered. However, descriptive tables for Russia have never been published. According to our classification some associations reported for mires in Scandinavia (Dierssen,

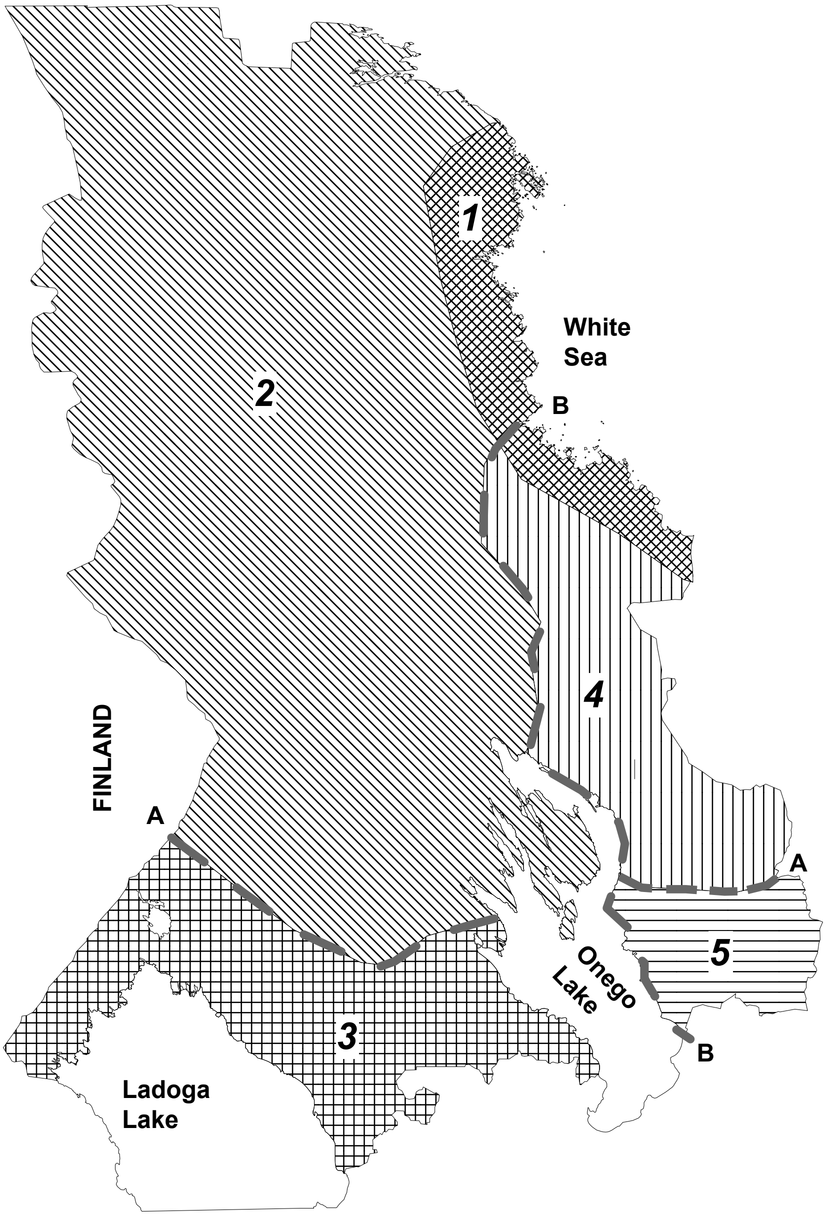

Fig. 19. Mire districts (1–5) of Karelia and their main mire massif types

1. White Sea Cost – lichen-rich *Sphagnum fuscum* raised bogs, 2. North and Central Karelia – Fennoscandian aapa mires, 3. Southern Karelia – eastern Finnish-western Russian *Sphagnum fuscum* raised bogs with *Calluna vulgaris* and *Chamaedaphne calyculata* (this type of bog is also common in the district 2), 4. Eastern Karelia – northeastern European aapa mires, 5. South- Eastern Karelia – *Sphagnum fuscum* raised bogs with *Chamaedaphne calyculata* (this type of bog is also common in the district 4).

A– A – south boundary of aapa mires, B – B – boundary between northwestern European and northeastern European types of bogs and aapa mires

1982) and Northwest Russia (Boch & Smagin, 1982) are subdivided into smaller ones while several new associations still requiring validation have been identified. The complexity of processing, the need to collect materials on a large scale and a failure to distinguish associations directly during field studies restrict the use of the floristic method in the classification of mire vegetation and rapid assessment of plant diversity especially in small regions.

Topological-ecological classification of vegetation. Topological and topological-ecological systems of classification are widely used in Scandinavia and Canada (Jeglum, 1991; Påhlsson, 1994; Racey et al., 1996). They are based on the combination of the ecological features of habitats with their phytocoenotic parameters. In order to distinguish between the lowest ranking units of classification dominant species and diagnostic groups of species are widely used. In topological classifications of mires the lowest ranking units are called mire types. Some authors define them as both homogeneous sites containing a single cenosis and complex sites (Eurola et al., 1984) for which Russian mire scientists use the term 'facies'. Others (Lindsay et al., 1985; Moen, 1985; Galten, 1987; Jeglum, 1991) understand mire types in terms of fairly uniform cenoses. The topological-ecological classification of vegetation developed for North Europe is the most detailed and logical system (Påhlsson, 1994). According to this system of classification mire vegetation falls into sixty-three types which belong to five main complexes. Each syntaxon is assigned a digital code (index). It has been noted that the types distinguished are essentially similar to phytosociological categories of associations and communities. Lists of main species are presented along with dominant species for each type. Many types are similar in terms of size to floristically distinguished associations; some are smaller while others include a broad spectrum of communities.

Topological-ecological classification of mire vegetation of Karelia. Based on the classification of vegetation compiled for North Europe a topological-ecological classification of Karelian mire vegetation was developed which employed existing data concerning releves together with the results of studies carried out in the areas to be protected. In order to divide these descriptions into preliminary phytocenoses twelve ecological groups of mire species known to Karelia were established (Kuznetsov, 1991). Such groups of species are widely used as regional groups by many phytocenologists in order to differentiate and characterise syntaxa (Nitsenko, 1969; Eurola, 1962; Galten, 1987). The presence or absence of certain ecological groups of species in a description or in a syntaxon is a better diagnostic criterion for classification than is the dominance of a particular species which may often be the result of arbitrary factors. The process of describing phytocenoses then involves an estimation of the occurrence of species in order to determine their syntaxonomic status and to distinguish diagnostic species.

The topological-ecological system of classifying Karelian mire communities consists of three steps (Table 10). Syntaxa are distinguished during the various steps according to ecological, topological and phytocoenotical criteria and features. The highest units of the classification, known as classes, are distinguished with regard to the level of water-mineral nutrition. There are four such classes: ombrotrophic, oligotrophic, mesotrophic and eutrophic, each representing specific levels of water-mineral nutrition. The ecological spectra of the oligotrophic and mesotrophic classes are similar to those proposed by Finnish authors (Eurola et al., 1984). According to Russian literature on mire ecology the oligotrophic class corresponds to meso-oligotrophic and mesotrophic conditions (Lopatin, 1954) while the mesotrophic class corresponds to mesoeutrophic and to some extent even eutrophic conditions.

The lowest unit in this system of classification is the association. This is identified in terms of the physiognomic and floristic features of communities, thus facilitating comparison with syntaxa distinguished by supporters of the dominant and floristic methods. In ombrotrophic and oligotrophic *Sphagnum* and grass communities, where the number of species is small, the plants that dominate in the main storeys are commonly used as diagnostic species as they provide the most comprehensive indication of the ecological conditions of a given habitat. As eutrophic communities often contain overwhelmingly dominant species only a large group of diagnostic species allows for such syntaxa to be distinguished. Associations are given names according either to the dominant or diagnostic species of the main storeys. These names include as many as three plant taxa written with intervening dashes. We do not add special endings to the names of plant species or the names of the authors who first identified one or other association, as is accepted in floristic classifications. Some associations are split up into sub-associations and variants with respect to the species that dominate particular storeys. In dwarf shrub-moss and grass-moss associations with the compositionally similar dwarf shrub-grass storeys sub-associations are distinguished with respect to dominant moss species with similar ecological requirements which replace each other either arbitrarily or during successions without any drastic changes to the structure of communities. Variants are distinguished according to the dominant grass storey species, the general species composition of the association remaining unchanged (Table 10).

Within each class groups of associations are distinguished by virtue of their proximity to the main elements of microrelief which differ in terms of hydrological conditions. As with the Scandinavian system of classification each class is subdivided into four groups. Group 1 consists of forested (tree-*Sphagnum*, tree-grass) communities characterised by highly variable hydrological conditions during the growing season which support the existence of the tree storeys. Communities which make up groups of forested associations have tree layers with a density of at least 0.2. Group 2 is formed by communities restricted to high hummocks (ridges) with groundwater levels which fall by 25–40 cm during the summer. Dwarf shrubs are of general occurrence in this group of mire communities. The group of lawn (carpet) communities (group 3) consists of various grass-*Sphagnum* associations in where groundwater levels fall by 10–20 cm during the growing season. Grass and grass-moss communities of hollows and flarks form group 4. In the ombrotrophic, oligotrophic and eutrophic classes all four groups are represented. By contrast, the mesotrophic class lacks hummock and carpet groups. Contrary to the systems of classification of North Europe (Påhlsson, 1994) and Finland (Eurola et al., 1984), spring mire communities do not form a separate class. Instead, they are included in a special group within the eutrophic class.

According to our system of classification there are fifty-one associations. Some of these have between two and eight sub-associations distinguished on the basis of the dominant species in the moss storey or the absence of a moss storey. Some associations occur as variants according to the dominant species in the grass-dwarf shrub storey (Table 10).

A complete list of plants was compiled, average numbers of species for each given releve calculated and highly constant (classes III–V after Braun-Blanquet) and diagnostic species were determined for each syntaxon. According to this system of classification the range of most associations is similar to that in our earlier floristic classification (Kuznetsov et al., 2000). However, higher steps of classification were distinguished on the basis of other features and these differ markedly from alliances, orders and classes in floristic classifications.

Table 10

Topological-ecological classification of mire communities of Karelia with characteristics of species content (A-D) in syntaxa and its comporation with classification of north Europe (E)

A – number of relevés, **B** – total number of species in syntaxa, **C** – average number of species in a single relevé, **D** – number of species with III–V classes of occurrence (41–100%); **E** – code of similar syntaxa in classification of north Europe (after Påhlsson 1994)

CODE	SYNTAXA	A	B	C	D	E
1	**CLASS** : OMBROTROPHIC					3.1
1.1	**Group** : tree-moss					3.1.1
	Association :					
1.1.1	*Pinus sylvestris - Ledum palustre - Sphagnum angustifolium*	39	60	18	20	3.1.1.2
1.1.2	*Pinus sylvestris - Chamaedaphne calyculata – Sphagnum angustifolium*	232	55	17	15	3.1.1.3
	Subassociation :					
1.1.2.1	*P. sylvestris - C. calyculata - S. fuscum*	81	55	18	20	
1.1.2.2	*P. sylvestris - C. calyculata – S. angustifolium*	151	53	16	15	
1.2	**Group :** hummock					3.1.2
1.2.1	*Chamaedaphne calyculata - Sphagnum fuscum*	598	70	15	17	3.1.3.1 (partly)
1.2.2	*Chamaedaphne calyculata - Sphagnum angustifolium*	580	55	15	11	3.1.3.1 (partly)
1.2.3	*Calluna vulgaris - Cladina* spp.	135	65	19	18	3.1.2.2
1.3	**Group** : carpet					3.1.3
1.3.1	*Eriophorum vaginatum – Sphagnum balticum*	324	70	10	7	3.1.3.5, 3.1.4.1
1.3.1.1	*E. vaginatum - S. balticum*	210	66	9	9	
1.3.1.2	*E. vaginatum - S. majus*	22	38	9	7	
1.3.1.3	*E. vaginatum - S. papillosum*	50	48	13	12	
1.3.1.4	*E. vaginatum - S. lindbergii*	9	38	11	7	
1.3.1.5	*E. vaginatum - S. fallax*	23	43	10	9	
1.3.1.6	*E. vaginatum - S. flexuosum*	10	38	14	9	
1.4	***Group** : hollow*					3.1.4
1.4.1	*Baeothryon cespitosum – Sphagnum balticum*	21	38	12	10	3.2.3.1b
1.4.1.1	*B. cespitosum - S. balticum*	12	38	12	10	
1.4.1.2	*B. cespitosum - S. majus*	9	28	11	11	
1.4.2	*Scheuchzeria palustris – Sphagnum majus*	384	55	10	7	3.1.4.1- 3.1.4.4
1.4.2.1	*S. palustris - S. balticum*	116	50	9	7	
1.4.2.2	*S. palustris - S. majus*	153	45	7	6	
1.4.2.3	*S. palustris - S. papillosum*	38	47	13	12	
1.4.2.4	*S. palustris - S. lindbergii*	19	31	10	9	
1.4.2.5	*S. palustris - S. cuspidatum*	18	23	8	4	
1.4.2.6	*S. palustris - S. fallax*	31	45	10	10	
1.4.2.7	*S. palustris - S. jensenii*	9	23	8	7	
1.4.3	*Rhynchospora alba - Sphagnum majus*	14	21	8	6	3.1.4.1- 3.1.4.4
1.4.3.1	*R. alba - S. balticum*	3	17	9	5	
1.4.3.2	*R. alba - S. majus*	8	18	7	8	
1.4.3.3	*R. alba - S. cuspidatum*	3	12	7	5	
1.4.4	*Scheuchzeria palustris – Hepaticae*	10	24	8	8	3.1.4.5
2	**CLASS :** OLIGOTROPHIC					3.2, 3.3
2.1	**Group**: tree-grass-moss					3.2.1, 3.3.1
2.1.1	*Pinus sylvestris - Carex lasiocarpa - Sphagnum angustifolium*	119	115	22	15	3.2.1.3 (partly)
2.1.1.1	*P. sylvestris - C. lasiocarpa - S. angustifolium*	91	115	21	16	
2.1.1.2	*P. sylvestris - C. lasiocarpa - S. fallax*	7	59	23	25	
2.1.1.3	*P. sylvestris - C. lasiocarpa - S. flexuosum*	6	66	24	22	
2.1.1.4	*P. sylvestris - C. lasiocarpa - S. centrale*	15	96	21	17	
2.1.2	*Betula pubescens - Carex lasiocarpa - Sphagnum angustifolium*	35	100	18	10	3.2.1.3
2.2.2.1	*B. pubescens - C. lasiocarpa - S. angustifolium*	29	97	17	10	
2.1.2.2	*B. pubescens - C. lasiocarpa - S. centrale*	6	64	23	16	

CODE	SYNTAXA	**A**	**B**	**C**	**D**	**E**
2.2	**Group** : hummock					3.2.2
2.2.1	*Carex lasiocarpa - Sphagnum fuscum*	110	103	20	22	3.2.2.1
2.3	**Group** : carpet					3.2.3, 3.3.3
2.3.1	*Molinia caerulea - Sphagnum papillosum*	141	113	20	15	3.3.2.1, 3.2.3.1b
	Variant : *a. Molinia caerulea – S. papillosum*	63	100	22	17	
	b. Baeothryon alpinum – S. papillosum	15	56	15	12	
	c. B. cespitosum – S. papillosum	63	83	20	14	
2.3.2	*Carex lasiocarpa - Sphagnum fallax*	503	120	16	11	3.2.4.1a 3.2.3.1a
2.3.2.1	*C. lasiocarpa - S. angustifolium*	238	108	17	11	
2.3.2.2	*C. lasiocarpa - S. papillosum*	141	115	17	13	
2.3.2.3	*C. lasiocarpa - S. fallax*	67	93	14	9	
2.3.2.4	*C. lasiocarpa - S. flexuosum*	25	50	11	10	
2.3.2.5	*C. lasiocarpa - S. centrale*	23	61	16	12	
2.3.3	*Carex rostrata – Sphagnum fallax*	131	68	11	10	3.2.4.1a
2.3.3.1	*C. rostrata - S. angustifolium*	27	42	10	11	
2.3.3.2	*C. rostrata - S. fallax*	53	65	11	11	
2.3.3.3	*C. rostrata - S. papillosum*	42	59	12	11	
2.3.3.4	*C .rostrata - S. riparium*	9	56	14	9	
2.4	**Group** : flark					3.2.4 3.3.3 (part)
2.4.1	*Carex lasiocarpa - Scheuchzeria palustris - Sphagnum balticum*	46	58	13	15	3.2.4.1 (partly)
2.4.1.1	*C. lasiocarpa - S. palustris - S. balticum*	24	57	15	17	
2.4.1.2	*C. lasiocarpa - S. palustris - S. majus*	22	52	10	7	
2.4.1.3	*C. lasiocarpa - S. palustris - S. jensenii*					
2.4.2	*Carex rostrata - Scheuchzeria palustris - Sphagnum majus*	81	58	11	10	3.2.4.1 (partly)
2.4.2.1	*C. rostrata - S. palustris - S. balticum*	30	56	11	11	
2.4.2.2	*C. rostrata - S. palustris - S. majus*	33	52	10	7	
2.4.2.3	*C. rostrata - S. palustris - S. flexuosum*	18	35	11	9	
2.4.3	*Rhynchospora alba - Menyanthes trifoliata - Sphagnum papillosum*	9	38	14	15	-
2.4.4	*Eriophorum polystachion*	6	26	11	9	3.2.4.2
2.4.5	*Carex rostrata*	17	69	12	8	3.3.3.1
3	**CLASS :** MESOTROPHIC					3.3, 3.4
3.1	**Group :** tree-grass					3.4.1
3.1.1	*Alnus glutinosa - Calla palustris*	5	102	36	19	3.4.1.3
3.1.2	*Picea abies - Calamagrostis canescens*	18	145	45	38	3.4.1.2 3.3.1.2
	a. P. abies - Calamagrostis canescens	9	134	48	46	
	b. P. abies - Phragmites australis	9	115	42	37	
3.1.3	*Pinus sylvestris - Calamagrostis canescens*	10	124	34	23	3.4.1.1 3.3.1.1
3.1.4	*Betula pubescens - Calamagrostis canescens*	13	120	26	20	3.4.1.2
3.1.5	*Salix cinerea*	2				3.3.1.3
3.4	**Group** : flark and swamp					3.3.4(part) 3.4.4(part)
3.4.1	*Phragmites australis - Menyanthes trifoliata*	11	65	12	7	3.3.4.1
3.4.2	*Carex acuta*	8	55	17	9	3.4.4.1
3.4.3	*Carex omskiana*	10	47	16	10	-
3.4.4	*Carex cespitosa*	14	90	16	7	3.4.4.1
3.4.5	*Carex diandra*	8	56	23	20	3.4.4.1
3.4.6	*Carex chordorrhiza*	24	52	11	9	3.3.3.1
3.4.6.1	*C. chordorrhiza - Menyanthes trifoliata*	17	48	11	8	
3.4.6.2	*C. chordorrhiza - Sphagnum obtusum*	7	23	11	11	
3.4.7	*Carex lasiocarpa - Menyanthes trifoliata*	211	150	16	5	3.3.3.1
3.4.7.1	*C. lasiocarpa - M. trifoliata*	147	150	15	5	
3.4.7.2	*C. lasiocarpa - Comarum palustre*	13	100	21	12	
3.4.7.3	*C. lasiocarpa - Sphagnum obtusum*	9	46	15	12	
3.4.7.4	*C. lasiocarpa - S. riparium*	8	70	19	10	
3.4.7.5	*C. lasiocarpa – S. subsecundum*	19	75	16	9	
3.4.7.6	*C. lasiocarpa - Warnstorfia exannulata*	8	71	21	14	
3.4.7.7	*C. lasiocarpa - Hamatocaulis vernicosus*	7	73	16	10	

End. table 10

CODE	SYNTAXA	**A**	**B**	**C**	**D**	**E**
3.4.8	*Carex limosa - Menyanthes trifoliata*	163	80	12	6	3.3.3.1
3.4.8.1	*C. limosa - M. trifoliata*	121	77	12	8	
3.4.8.2	*C. limosa – Sphagnum obtusum*	15	52	14	12	
3.4.8.3	*C. limosa - S. subsecundum*	18	52	14	12	
3.4.8.4	*C. limosa - Warnstorfia exannulata*	8	33	10	6	
3.4.9	*Rhynchospora fusca*	21	28	12	13	3.3.3.4
3.4.10	*Calamagrostis neglecta*	5	52	13	2	3.3.4.1
3.4.11	*Equisetum fluviatile*	22	87	12	6	3.3.4.1
3.4.12	*Menyanthes trifoliata*	9	63	17	14	3.3.4.1
3.4.13	*Comarum palustre*	9	67	18	15	3.3.4.1
4	**CLASS :** EUTROPHIC					3.4
4.1	**Group :** tree-moss					3.4.1(part)
4.1.1	*Pinus sylvestris - Sphagnum warnstorfii*	41	178	32	25	3.4.1.1
	P. sylvestris - Phragmites australis – S. warnstorfii	14	149	39	28	
	P. sylvestris - Carex lasiocarpa – S. warnstorfii	12	96	26	19	
	P. sylvestris - Molinia caerulea – S. warnstorfii	15	117	30	27	
4.2	**Group :** hummock					3.4.2
4.2.1	*Equisetum palustre - Sphagnum warnstorfii*	58	186	33	19	3.4.2.1a
4.2.1.1	*E.palustre - S. warnstorfii*	51	186	34	19	
	a. E. palustre - S. warnstorfii	26	147	29	21	
	b. Polygonum bistorta - S. warnstorfii	25	145	39	19	
4.2.1.2	*E.palustre - Tomenhypnum nitens*	7	77	21	16	
4.2.2	*Molinia caerulea - Sphagnum warnstorfii*	71	120	21		3.4.2.1a
4.2.2.1	*M.caerulea - S. warnstorfii*	48	120	22	16	
	a. Molinia caerulea - S. warnstorfii	30	116	24	16	
	b. Baeothryon cespitosum	6	50	21	18	
	c. Baeothryon alpinum	12	74	21	19	
4.2.2.2	*M.caerulea - S. subfulvum*	23	68	20	21	
4.2.3	*Carex lasiocarpa - Sphagnum warnstorfii*	89	130	18		3.4.2.1a
4.2.3.1	*C.lasiocarpa – S. warnstorfii*	70	129	18	16	
	a. Carex lasiocarpa - S. warnstorfii	54	121	19	13	
	b. Phragmites australis - S. warnstorfii	16	65	16	13	
4.2.3.2	*C.lasiocarpa - S. teres*	9	62	18	15	
4.2.3.3	*C.lasiocarpa - S. subfulvum*	10	30	14	13	
4.3	**Group :** carpet					3.4.2
4.3.1	*Carex lasiocarpa - Campylium stellatum*	29	105	21	14	3.4,2,1b
4.3.2	*Schoenus ferrugineus - Campylium stellatum*	22	58	17	13	3.4.2.1c
4.4	**Group :** flark					3.4.3
4.4.1	*Carex lasiocarpa - Scorpidium scorpioides*	20	68	15	9	3.4.3.3
4.4.2	*Carex limosa - Scorpidium scorpioides*	12	50	14	14	3.4.3.3
4.4.3	*Carex livida - Menyanthes trifoliata*	70	75	11	11	3.4.3.3
4.4.3.1	*C. livida - M. trifoliata*	60	75	11	12	
4.4.3.2	*C. livida – Scorpidium scorpioides*	10	35	13	9	
4.5.	**Group :** spring					3.5.1, 3.5.2
4.5.1.	*Epilobium hornemanni - Montia fontana - Philonotis fontana*					3.5.1.2
4.5.2.	*Cratoneuron* spp.					3.5.2.2
4.5.3.	*Paludella squarrosa*					3.5.2.3

The topological-ecological classification of Karelian mire vegetation was compared with that of North Europe (Påhlsson, 1994). Unequally ranking, compositionally and ecologically similar syntaxa were selected from Scandinavian mires for almost every association identified. Their codes are given in Table 10. However, these classifications vary greatly in terms of the range of some classes and of some lowest-ranking units such as ‘types’ in the system of classification employed in North Europe and ‘associations’ in our own classification. Because the oligotrophic and mesotrophic grass and grass-moss communities of Karelian mires are subdivided into smaller units certain new associations may be distinguished. On the one hand, Karelia lacks the mire communities characteristic of the nemoral, mountain and tundra areas of Scandinavia and the coastal mires of Norway. At the same time, some associations restricted to areas with a more continental climate occur in Karelia and eastern Finland at the western boundaries of their distribution areas and have not been reported anywhere in Sweden or Norway. Examples include ombrotrophic dwarf shrub-*Sphagnum* communities with *Chamaedaphne calyculata* as well as mesotrophic and eutrophic communities with *Carex omskiana, Bistorta major, Betula humilis* and *Ligularia sibirica*. Associations of *Carex livida, Rhynchospora fusca* and *Schoenus ferrugineus*, communities with moss storeys dominated by *Sphagnum* *subfulvum, S. subnitens* and *S. pulchrum*, reach the eastern boundaries of their distribution areas in Karelia. In terms of species composition the above Karelian communities differ greatly from those found in Scandinavia. Quantitative indices of floristic diversity are given for the first time for each association, sub-association and variant of association (Table 10).

This system of classification is open-ended insofar as that new syntaxa may be included and their ranks revised. As the scope of the study is extended, the areas covered by associations and sub-associations will be specified and their geographic variants identified. This classification is convenient for solving scientific and practical problems as, unlike the floristic method, it allows many associations to be easily identified in the field. Most of the associations distinguished cover extensive areas in the boreal zone of Eurasia. However, their species composition varies from one region to the next. As some associations and sub-associations occur only in Fennoscandia the nature conservation value of the mires in which they occur increases. A subsequent study of mires in Fennoscandia and Russia will increase our knowledge of their plant cover diversity while generalisation of the data thus produced will enable us to improve and expand our system of classification.

The conservation of biological diversity of ecosystems and their components is maintained most successfully through the establishment of a dense network of protected areas ranking from large national parks and nature reserves to small nature monuments. In many European countries mire ecosystems have either been profoundly transformed or totally destroyed. Most Karelian mires are still today in either a natural or only slightly disturbed state. Forest drainage performed in the 1960s–1980s on 700 000 ha of mires and paludified land (13% of total area of such land in Karelia) has not resulted in the disappearance of rare mire plant species, rare associations and types of mire massifs. However, in southern Karelia, where over 50% of mires have been drained, important mires supporting berries were destroyed and the number of mesotrophic and eutrophic mires containing rich flora fell sharply. In order to maintain the diversity of mire systems a number of large-scale studies and other activities have been conducted. Today some 130 000 ha of mires (i.e. only 3% of all Karelian mires) lie within protected territories (Antipin & Kuznetsov, 1998). Protected territories include all types of mire massifs as well as most mire associations and mire species. However, the current extent of protected mires is too small to properly conserve their diversity and to enable mires to fulfil their regulating biospheric functions. The establishment of several new national parks (Kalevala, Tuulos and Koitajoki) together with a network of landscape and mire zakazniks and nature monuments will enable us to preserve the full diversity of mires for the benefit of future generations.

Conclusion. Structural analysis of mire ecosystems has shown them to be highly diverse. Karelia has nine geographic types of mire massifs, some of which occur as latitudinal variants. Five types of massifs lie at the boundaries of their distribution areas. This in itself imparts the mire systems of the region with certain unique features.

The topological-ecological system of classification of plant communities developed for the mires of the region has enabled us to assess the wide diversity of these mires and to identify the characteristics of their vegetation cover. This classification includes fifty-one associations belonging to four different classes. Many Karelian mire communities are compositionally similar to those of Scandinavia.

The present network of protected mires is too small to ensure the proper maintenance of Karelian mire ecosystem diversity. It should be expanded through the establishment of new protected territories such as national and nature parks, zakazniks and nature monuments.

2.2.2. Mire and paludified habitats

Introduction. Karelia extends 600 km from north to south and varies in climatic, geomorphological, biotic and other zonal and azonal characteristics. Mires and paludified forests cover 5.35 million hectares and make up 37% of Karelia's forested area. Open and sparsely forested mires with stand densities of less than 0.3 account for 3.5 million hectares while forest mires and paludified forests occupy 1.8 million hectares. (Pyavchenko & Kolomytsev, 1980). Thus, the wetland forests that cover about one third of the Karelian Republic contribute greatly to environmental diversity. At the same time, wetland forests are generally subdivided into 1) paludified (paludifying) stands with a peat layer of up to 30 cm, and 2) forest mires with a peat layer of over 30 cm. This criterion is based on differences in the soils (Pyavchenko, 1963), hydrology and topology of paludified forest and mire habitats (Kolomytsev, 2001).

Mires and paludified forests are too complex and diverse to be described solely on the basis of the above criteria and characteristics. It is important, therefore, to provide *evidence for the spatial distribution of various mire and paludified habitats* using a landscape-typological approach to the natural demarcation of Karelia* (Volkov et al., 1990, 1995).

Methods. Our field study of mires and paludified forests was carried out on landscape profiles taken in various landscapes perpendicular to the long axes of orientation of landforms. A topographic survey was performed in order to estimate the area covered by three categories of wetlands, namely, 1) paludified forest lands (with peat deposits up to 30 cm thick); 2) mire forest lands (with peat layers of over 30 cm thick); and 3) open (unforested) mires (with peat deposits of over 30 cm thick). The vegetation of wetlands was described and their extent along the profile estimated. The presence of peat and its thickness was determined by drilling peat deposits as far as the mineral bottom.

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* For the numbers and full names of landscape types, see the Section .2.1.3. 'Assessment of the diversity of forest communities'. Data on two to three profiles are presented separately in diagrams for some types of landscape.

Wetland habitats types were then grouped together in accordance with the system established for Karelia (Pyatetsky & Medvedeva, 1967).

Sixteen profiles totalling 70 km in length were taken in the north-taiga subzone in twelve out of sixteen landscape types identified and twenty-eight profiles totalling 143 km in length were taken in the mid-taiga subzone in sixteen types of Karelian landscape. About 300 descriptions of the ground plant cover in mire facies and paludified forests were made.

Diversity of mire and paludified forest habitats in the north-taiga subzone. Paludified (paludifying) forests growing on soils containing approximately 30 cm thick peat layers are common in the taiga. Forming an integral part of mire systems they are bounded by or make up individual massifs in topographic lows and in the lower portions of hills and ridges. Although this category of wetlands is widespread it can only be identified by the drilling of peat deposits. In physiognomical terms paludified forests do not usually differ in typological spectrum and vegetative cover from forest mires with peat deposits of up to several metres thickness. By contrast, their distribution and the proportions of various groups of forest types vary substantially according to the type of landscape

Paludified pine stands. In the north-taiga subzone pine stands dominate paludified habitats in most landscapes, accounting for between 3 and 25% of total area except in spruce-dominated types. In plain landscapes pine forests comnsist mostly of oligotrophic or meso-oligotrophic *Sphagnum* stands with poor vegetative cover (Fig. 20). Dwarf-shrub and/or cottongrass-*Sphagnum* mesotrophic pine stands are more characteristic of glaciofluvial and denudation-tectonic landscapes with rugged land surfaces. In such locations topographic conditions are conducive to the formation of systems of circulating moistening associated with deluvial and groundwater nutrition in paludified habitats. The dwarf shrub-*Sphagnum* pine forest group is dominated by *Vaccinium myrtillus-Sphagnum* and *Ledum-Sphagnum* stands. Commonly occurring in their vegetative cover are forest grasses and dwarf shrubs. Mesotrophic sedge-*Sphagnum* pine stands typically grow at the point of contact between dwarf shrub-*Sphagnum* pine stands and open mesotrophic mires. In other words, they are far more common than the previous two groups and do not form compact massifs (Fig. 20). Grass-*Sphagnum* paludified pine stands are very scarce in the north-taiga subzone and cover less than 1% of each landscape type.

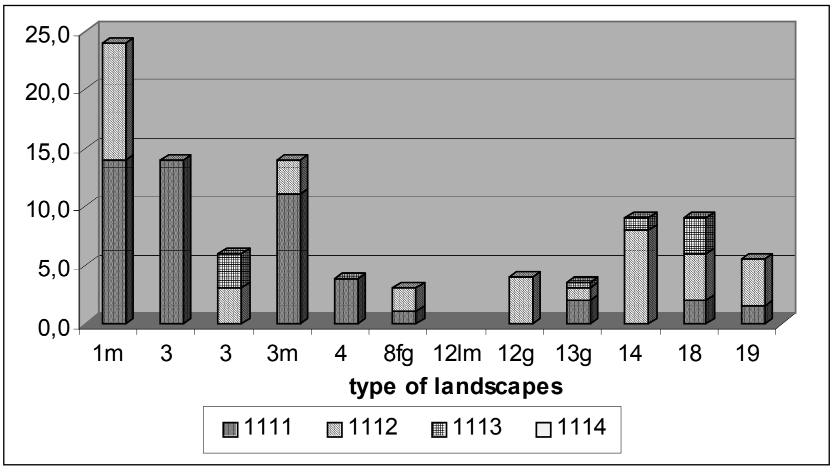

Fig. 20. Distribution of groups of paludified pine forest types (with peat deposits of up to 30 cm) within various landscape types in the north-taiga subzone of Karelia (%)

Groups of paludified forest types: 1111 = oligotrophic Sphagnum pine stands; 1112 = mesotrophic dwarf-shrub and/or cottongrass-Sphagnum pine stands; 1113 = mesotrophic sedge-Sphagnum pine stands; 1114 = eutrophic and mesotrophic grass-Sphagnum pine stands

Paludified spruce stands. Spruce is less common in paludified habitats than pine, especially in pine-dominated plain landscapes (Fig. 21). However in other types of pine landscapes spruce stands cover between a third and a half of the paludified land area. In spruce-dominated landscapes (1m, 12m, 12g) they account for at least a half of this land category. Long-stem moss spruce stands are fairly scarce in Karelia and extremely rare in northern Karelia. The dominant type of paludified spruce stand, *Vaccinium myrtillus-Sphagnum*, is the poorest in terms of vegetative cover. Spruce forests belonging to the sedge-grass-*Sphagnum* group contain a much broader spectrum of plant groups and species than the *Vaccinium myrtillus-Sphagnum* type and is found in all types of landscape. However, the proportion of forest cover which it account for varies from less than 1 to 5%. Grass-mire spruce stands are the most diverse in terms of vegetative cover and incorporate both shrubs and undergrowth. They are also found in all types of landscape but, as with sedge-grass-*Sphagnum* spruce stands, they account only for small fragmented areas.

Paludified birch stands may be classified as primeval because in the paludified state they form long-lived communities. In north-taiga landscapes paludified birch stands are scarce. They occur mostly in plain landscape

(Fig. 22) where they make up 0.5 to 5% of the forest cover. A grass-mire group of birch stand types prevails and is the most diverse in terms of plant groups. These environments are fairly conducive to the growth of birch.

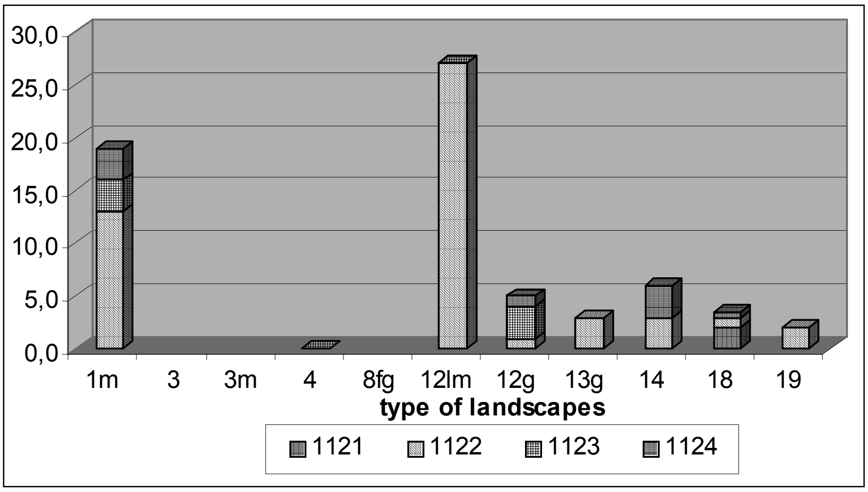

Fig. 21. Distribution of groups of paludified spruce forest types (with peat deposits of up to 30 cm) within various landscape types in the north-taiga subzone of Karelia (%)

Groups of paludified forest types: 1121 = mesotrophic long-stem moss spruce stands; 1122 = mesotrophic bilberry-*Sphagnum* spruce stands; 1123 = mesotrophic sedge-grass-*Sphagnum* spruce stands; 1124 = eutrophic grass-mire spruce stands

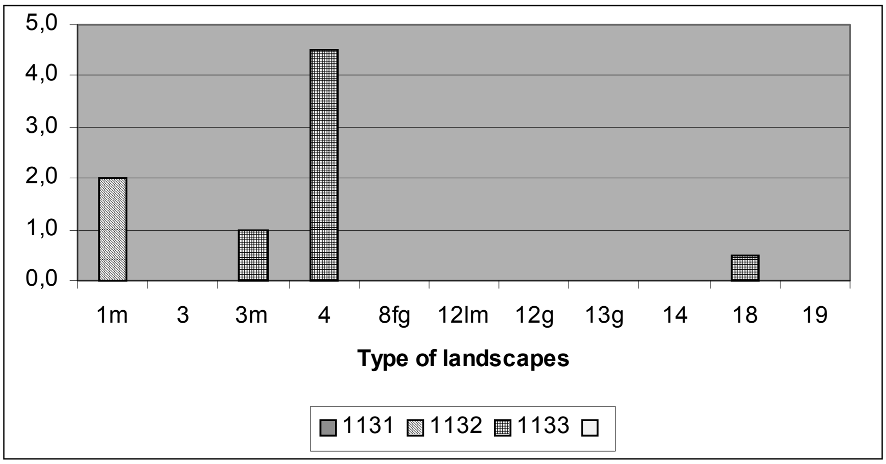

Fig. 22. Distribution of groups of paludified birch forest types (with peat deposits of up to 30 cm) growing in various types of landscape in the north-taiga subzone of Karelia (%)

Groups of paludified forest types: 1131 = mesotrophic sedge-*Sphagnum* birch stands; 1132 = mesotrophic grass-*Sphagnum* birch stands; 1133 = eutrophic grass-mire birch stands

Forest mires are characterised by well-developed stands growing on peat soils with peat deposits varying in thickness from 30 cm up to several metres. Groupings of forest mire types correspond to those of paludified forests. Forest mires differ from paludified forests in that paludified forests are always primary, i.e. the forest cover existed before paludification began and persists in spite of the process. Forest mires or individual patches of forest vegetation may remain primary from the early stages of paludification or may emerge as secondary patches on open mires as a result of changes in the hydrological system at the root layer of peat which promote the invasion of woody plants (Pyavchenko, 1963, Kolomytsev, 1993, 2001).

Mire pine forests grow in all types of north-taiga landscapes. This suggests that this formation is resistant to changes in soil and environmental conditions in which root systems are not supplied with nutrients from the underlying mineral horizon. Poor pine stands of *Sphagnum* and dwarf shrub- (cottongrass)-*Sphagnum* groups are most common (Fig. 23). These are typically the poorest in terms of plant species diversity. In most landscape types mesotrophic sedge-*Sphagnum* pine stands cover a relatively significant area (1 to 6%). The most diverse grass—Sphagnum pine stands are characteristic only of pine-dominated landscapes (3m, 14). In other landscapes they are highly fragmented and very small in area.

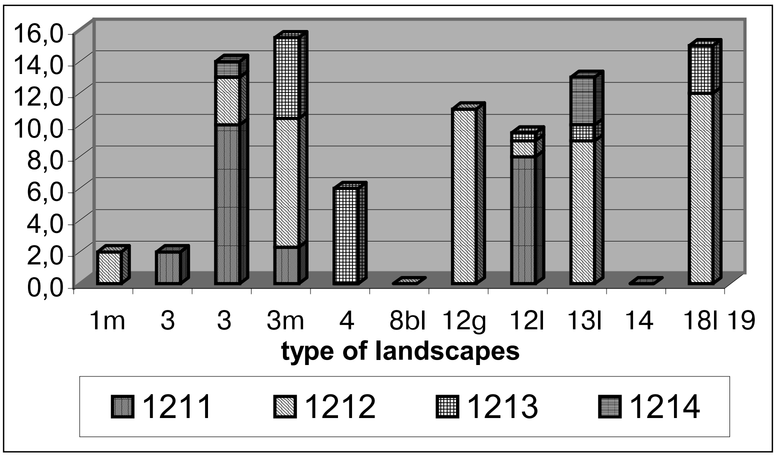

Fig. 23. Distribution of groups of mire pine forest types (with peat deposits greater than 30 cm) growing in various landscape types in the north-taiga subzone of Karelia (%)

Groups of mire forest types: 1211 = oligotrophic *Sphagnum* pine stands; 1212 = mesotrophic dwarf shrub- and/or cottongrass-*Sphagnum* pine stands; 1213 = mesotrophic sedge-*Sphagnum* pine stands; 1214 = eutrophic and mesotrophic pine stands

Mire spruce forests typically grow in denudation-tectonic landscapes with rugged relief in which systems of circulating moistening prevail in topographic lows (Fig. 24). In flatland landscapes, where spruce stands are highly paludified, spruce readily gives way to forest-free grass-moss or pine mires.

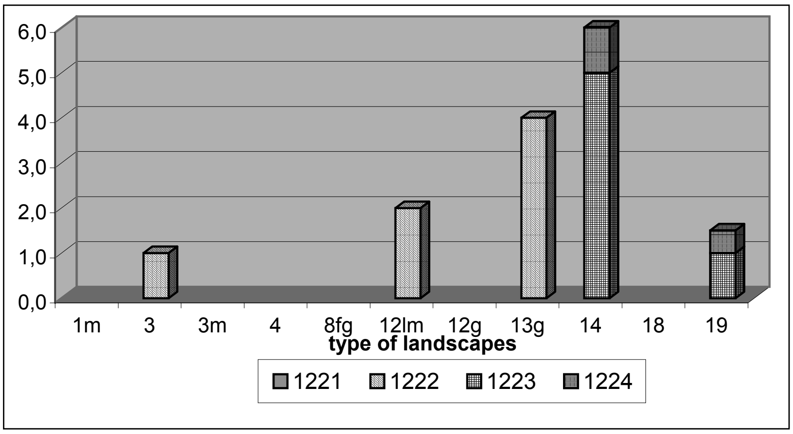

Fig. 24. Distribution of groups of mire spruce forest types (with peat deposits greater than 30 cm in thickness) growing in various landscapes in the north-taiga subzone of Karelia (%)

Groups of mire forest types: 1221 = mesotrophic long-stem moss spruce stands; 1222 = mesotrophic bilberry-*Sphagnum* spruce stands; 1223 = mesotrophic sedge-grass-*Sphagnum* spruce stands; 1224 = eutrophic grass-mire spruce stands

The proportion of spruce stands in the forest cover is not large but the presence of groups of mire spruce forest types is important for the diversity of habitats especially in pine-dominated landscapes (landscapes 3, 13g, 14, 19).

Open mires make the greatest contribution to the diversity of habitats in Karelian landscapes. In the north-taiga subzone they cover from 40 to 60 % of all wetland categories in plain landscapes and from 10 to 40 % in glaciofluvial and denudation-tectonic landscapes (Fig. 25). Most landscapes are dominated by oligotrophic habitats (between one third and one half of all mire lands) with extremely poor plant species composition. Mesotrophic mires with a broader spectrum of habitats are also widespread. They feature both simple sedge-*Sphagnum* plant groups and highly developed aapa complexes. Eutrophic mires do not commonly form individual massifs. In most landscapes they occur as small patches: Nevertheless, it is in these habitats that plants diversity is at its greatest.

Diversity of mire and paludified habitats in the mid-taiga subzone. *Paludified pine forests* occur in practically all landscape types in the mid-taiga subzone. They are most significant in highly paludified plain landscapes (3, 4) and in pine-dominated highly or moderately paludified landscapes of denudation-tectonic genesis (13, 14) (Fig. 26).

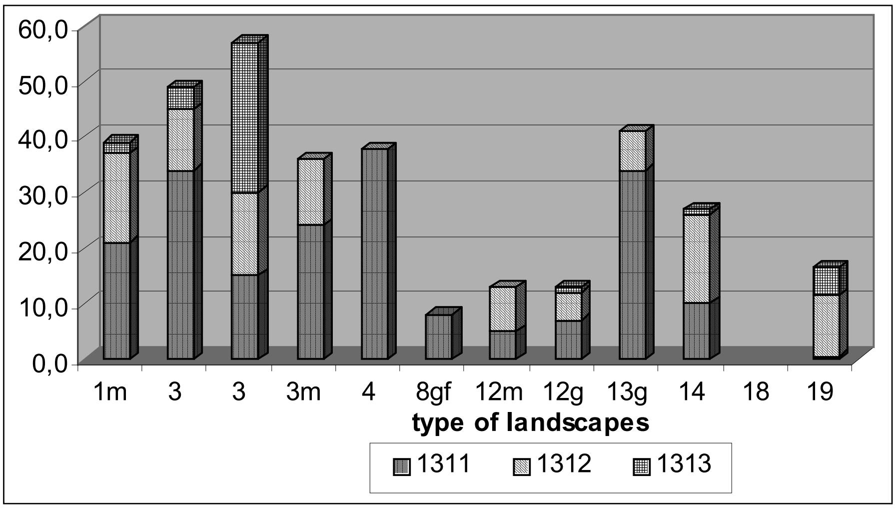

Fig. 25. Distribution of open mire types in Karelian north-taiga landscapes

Mire types: 1311 = oligotrophic, 1312 = mesotrophic, 1312 = eutrophic

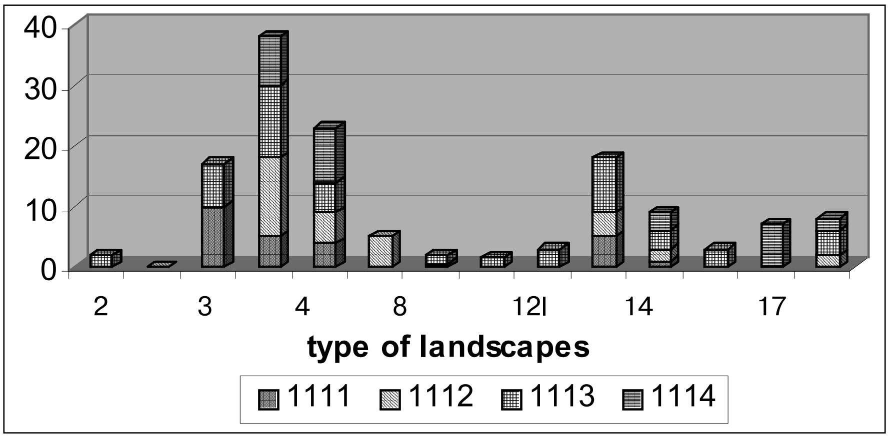

Fig 26. Distribution of groups of paludified pine forest types (with peat deposits of up to 30 cm) growing in various landscape types in the mid-taiga subzone of Karelia (%)

Groups of paludified forest types: 1111 = oligotrophic *Sphagnum* pine stands;1112 = mesotrophic dwarf shrub- and/or cottongrass-*Sphagnum* pine stands; 1113 = mesotrophic sedge-*Sphagnum* pine stands; 1114 = eutrophic and mesotrophic grass-*Sphagnum* pine stands

The four groups of paludified pine forest types cover roughly equal proportions of these types of landscape. Unlike the north-taiga subzone all landscapes here are dominated by mesotrophic sedge- and grass-*Sphagnum* habitats. They display the greatest degree of plant diversity whereas oligotrophic *Sphagnum* and poor mesotrophic dwarf shrub-*Sphagnum* habitats are less diverse.

Paludified spruce forests. Like pine forests these are common in all types of mid-taiga landscapes. The largest paludified spruce stands occur in spruce-dominated landscapes (2, 12g and 16). The dominant forest group in such landscapes is *Vaccinium myrtillus-Sphagnum* spruce which is the poorest in terms of plant diversity (Fig. 27).

Characteristic of the mid-taiga subzone are mesotrophic and eutrophic sedge-grass-*Sphagnum* and grass-mire spruce growing in plain landscapes (2, 3, 4, 5). These habitats display the greatest degree of species diversity. They are scarce in landscapes with rugged relief and grow as narrow patches along rivers, creeks and seasonal streams.

In the mid-taiga subzone *mire pine forests* contribute greatly to the diversity of habitats and are found growing in all landscape types. In some morphogenetic landscape variations they act as dominant or co-dominant ecosystems and cover from 20 to 35 % of habitats (landscapes 3, 8, 14, 18) (Fig. 28). These landscapes are generally dominated by pine which persists on mires.

In other spruce and pine landscapes mire pine stands make up not more than 10 % of habitats. However, groups of forest types generally display a limited spectrum with species-poor oligotrophic *Sphagnum* pine stands and mesotrophic dwarf shrub- and/or cottongrass-*Sphagnum* groups generally dominating.

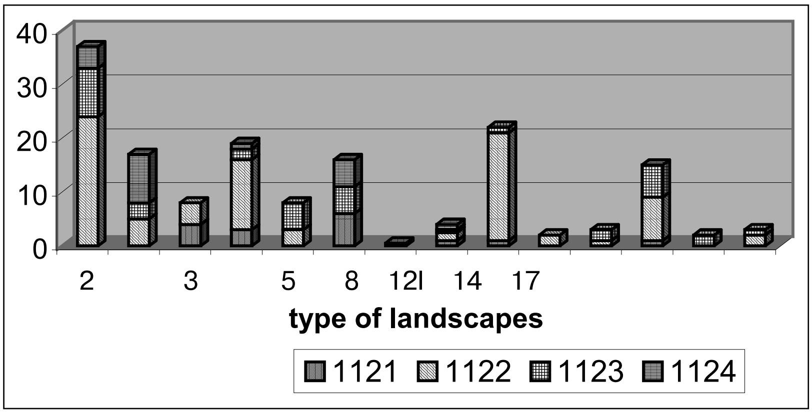

Fig. 27. Diversity of groups of paludified spruce forest types (with an up to 30 ñm thick peat deposit) occurring in various landscapes in the mid-taiga subzone of Karelia (%)

Groups of paludified forest types: 1121 = mesotrophic long-stem moss spruce stands; 1122 = mesotrophic blueberry-*Sphagnum* spruce stands; 1123 = mesotrophic sedge-grass-*Sphagnum* spruce stands; 1124 = eutrophic grass-mire spruce stands

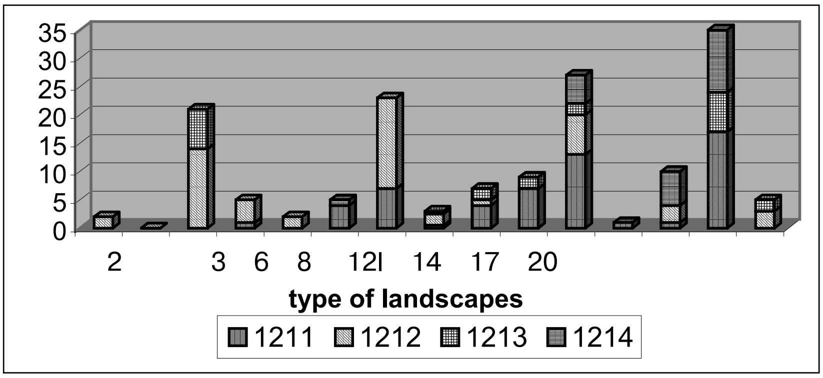

Fig. 28. Distribution of groups of mire pine forest types (with peat deposits greater than 30 cm) growing in various landscape types in the mid-taiga subzone of Karelia (%)

Groups of paludified forest types: 1211 = oligotrophic *Sphagnum* pine stands; 1212 = mesotrophic dwarf shrub- and/or cottongrass-*Sphagnum* pine stands; 1213 = mesotrophic sedge-*Sphagnum* pine stands; 1214 = eutrophic and mesotrophic grass-*Sphagnum* pine stands

Mire spruce stands. Unlike paludified spruce forests mire spruce stands are far less common in all mid-taiga landscapes (Fig. 29) and contribute no more than 10 % of the vegetative cover, suggest ing that spruce is less tolerant of overmoistened soils. As with mire pine forests these are more characteristic of landscapes with spruce habitats (2, 6, 16).

Only one or two groups of mire spruce stands occur in plain, glaciofluvial and certain denudation-tectonic landscapes. The species composition of plants and their groups (long-stem moss and *Vaccinium myrtillus*-*Sphagnum*) is extremely poor. The greatest contribution to biodiversity is made by mesotrophic sedge-grass-*Sphagnum* and eutrophic grass-*Sphagnum* mire spruce stands but these account for less than 1 to 4% of habitats in most landscapes.

Mire birch forests in the mid-taiga subzone are restricted to landscapes profoundly affected by agricultural development. In most environments, especially in glaciofluvial landscapes, they result from human activities, primarily drainage of mires or parts of mires (Fig. 30). In spite of this, birch stands growing on mires make a significant contribution to the biodiversity of Karelian taiga.

Open mires occur in all types of mid-taiga landscapes but are less common than in the north-taiga subzone due to the higher proportion of forested wetland (Fig. 31). Their contribution to the structure of ecosystems is most significant in plain (2 and 3) and denudation-tectonic landscapes (13 and 14).

Open mires are mostly oligotrophic or mesotrophic. Oligotrophic mires typically bear few plant species whereas mesotrophic mires often contain compositionally contrasting plant associations. Together with landscape type 12g these landscapes contain the majority of mires suitable for forest reclamation. As a consequence virgin eutrophic mires are very scarce. Mesotrophic mires prevail in fluvioglacial (6,8 and 10) landscapes as well as in one denudation-tectonic landscape type (16). In these landscapes open mires are highly fragmented and contribute greatly to the diversity of ecosystems.

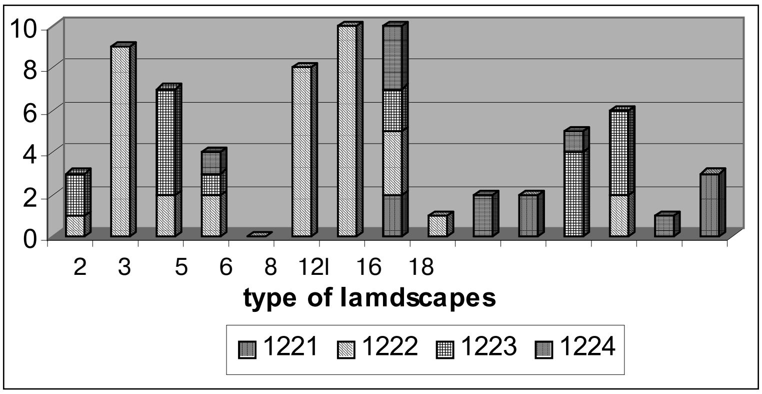

Fig. 29. Distribution of groups of mire spruce forest types (with peat deposits greater than 30 cm in thickness) growing in various landscapes in the mid-taiga subzone of Karelia (%)

Groups of mire forest types: 1221 = mesotrophic long-stem moss spruce stands; 1222 = mesotrophic bilberry-*Sphagnum* spruce stands; 1223 = mesotrophic sedge-grass-*Sphagnum* spruce stands; 1224 = eutrophic grass-mire spruce stands

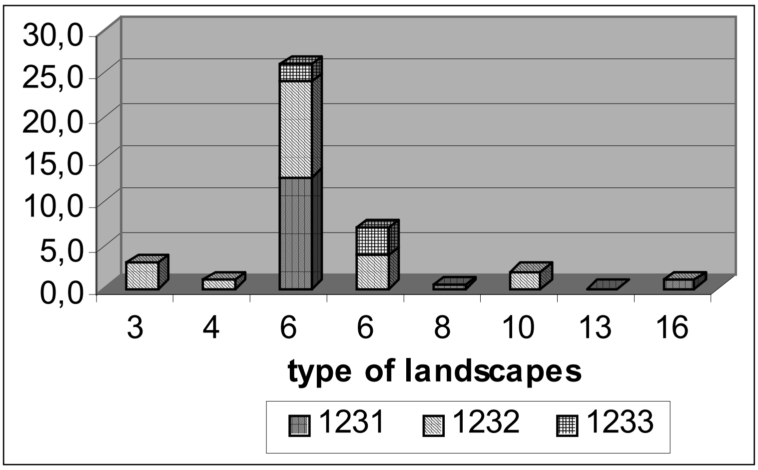

Fig. 30. Distribution of groups of mire birch forest types (with peat deposits of over 30 cm) growing in various landscapes in the mid-taiga subzone of Karelia (%)

Groups of mire forest types: 1231 = mesotrophic sedge-*Sphagnum* birch stands; 1232 = mesotrophic grass-*Sphagnum* birch stands; 1233 = eutrophic grass-mire birch stands

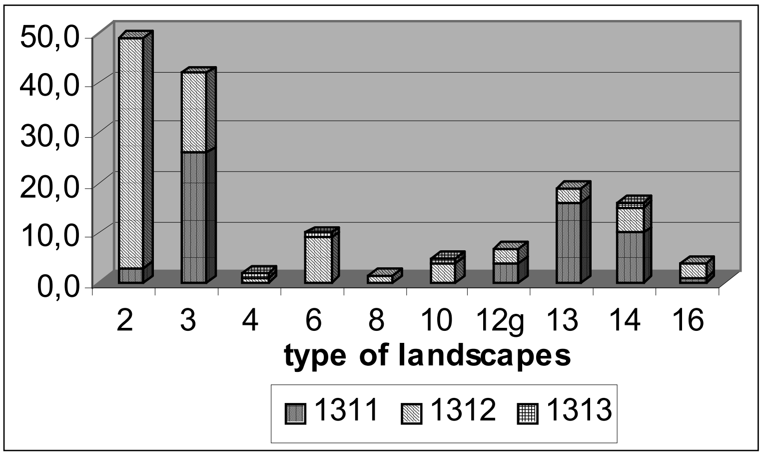

Fig. 31. Types of open mires in Karelian mid-taiga landscapes

Mire types: 1311 = îligotrophic, 1312 = mesotrophic, 1313 = eutrophic

Conclusion. In Karelia paludification increases habitat diversity as various environments are formed on wetlands. However, mire formation tends to give rise to structurally simple ecosystems, thus reducing biotic diversity. The clearest examples of this are heavily paludified landscapes of limnoglacial and denudation-tectonic genesis. In such landscapes vast areas are already dominated by forest, oligotrophic grass-*Sphagnum* or poor mesotrophic habitats containing few plant species. Paludified or mire habitats with relatively high plant diversity typically cover not more than 10% of each landscape type studied.

2.3. Grasslands

Introduction. Like all Fennoscandian countries Karelia is rather poor in grasslands. The proportion of grassland (less then 1%) is lower not only than that of Sweden, the southern part of which lies in the nemoral zone, but probably also of neighbouring Finland. At first sight Karelia appears to be a typical Fennoscandian country with a few areas of primary flooded meadows occurring in small patches restricted to the Vodla river basin. Small areas of coastal grassland extending along the coastline of the White Sea are also primary. All other grasslands in Karelia are of secondary origination. Sometimes known as traditional rural biotopes, they have resulted from traditional agricultural land-use techniques, i.e. grazing and mowing. Thus the grasslands of Karelia are mostly located in areas with a long history of agricultural colonisation.

One of the consequences of 20th century technological progress in Northern Europe was a marked decrease in the area of grassland. When the Karelian Labour Commune was established in 1920 its regional boundaries enclosed some 231 000 ha of grassland. With the incorporation of the North Ladoga region and the Karelian Isthmus into Karelia in 1940 the total grassland area increased to 360 000 ha. However, by the late 1990s it had fallen to little above 127 000 ha, a mere 0.71% of Karelian territory. The situation in Sweden and Finland is similar. The drop in grassland area was mainly caused by the mechanisation of agriculture followed by decline in horse livestock and a large-scale input of agricultural products from other regions resulting in a reduction of local production. It should be noted that the collapse of agriculture also had positive consequences for Karelian grasslands as some fields were abandoned and the total area of meadowland increased slightly. However this did little to help. The trends emerging over the last few years are especially discouraging. The area of grasslands stabilised in seventies, for a time following the economical collapse in the 1990s but is now once again in danger. If this latest trend continues between a half and two-thirds of Karelian grasslands are likely to be lost during the nearest fifteen years.

At the same time the contribution made by grasslands to regional biodiversity is much greater than their modest area might suggest. Up to 30% of Karelia's terrestrial invertebrate species (particularly insects) and many vertebrate and vascular plant (over 20%) species are obligate grassland species. Moreover, grasslands are important for the life cycle of numerous birds and mammals including those which are not strictly regarded as grasslands species. Many of these are listed in the regional Red Data Books of rare and endangered species. Thus, 44 vascular plant species found in grasslands are included in the Red Data Book of Karelia (1995) and 67 species (only those species which could be found in Karelia are counted) – in the Red Data Book of East Fennoscandia (1998).

In terms of the biodiversity of communities grasslands make up at least one third of all communities. Many types of grasslands are rare and should be protected by, for example, inclusion in the Green Book of Karelia when it will be worked out.

Typology of Karelia grasslands. The typology of communities (including grassland communities) represents one of the most acute problems in botany today. The system of classification drawn up by Shennikov (1941) and commonly used in north-western Russia is far from perfect as its creator himself admitted. With Shennikov concentrating solely on dominant communities and failing to formulate clearly the sizes of communities and their syntaxa, occasional attempts have since been made to correct his classification or render it more precise. One improved version provided the basis for the typology used by Marianna Ramenskaya in her monograph 'Meadow vegetation of Karelia' (1958).

In the neighbouring Nordic countries system of classification combining dominant communities with ecological factors developed at the request of the Nordic Council of Ministers by a group led by Lars Pahlsson (Påhlsson, 1994) has become popular over the last five years. Although this system is also short of perfect it has some advantages. One of these derives from the fact that it was originally developed to classify the vegetation of such an integral natural complex as the whole of Fennoscandia. Therefore when discussing types of Karelian grasslands the present author assumed that it would be beneficial to combine the approaches of Shennikov and Pahlsson. It should be noted that Pahlsson considered the basic unit of meadow classification to be something akin to the association although Shennikov and Ramenskaya (1958) treated these as formations which could be further divided into smaller associations.

The main Karelian grassland associations are presented in an ecological scheme arranged according to soil richness and moisture (fig. 32). They are often poorly defined and continually overlap one another and even other types of vegetation (e.g. mires and forests). The crossing of dotted lines on the diagram corresponds roughly to mesic mesotrophic meadowland. One can quickly see that most grassland types occur in hydric oligotrophic environments although the total area of such meadows is not large. 90% of Karelian grassland area is situated in the upper right corner of the diagram.

This is not a hierarchical system of typology and communities are not combined into larger syntaxa. However, they are divided up into groups according to moisture conditions which represents the single most important environmental factor in Karelian ecosystems.

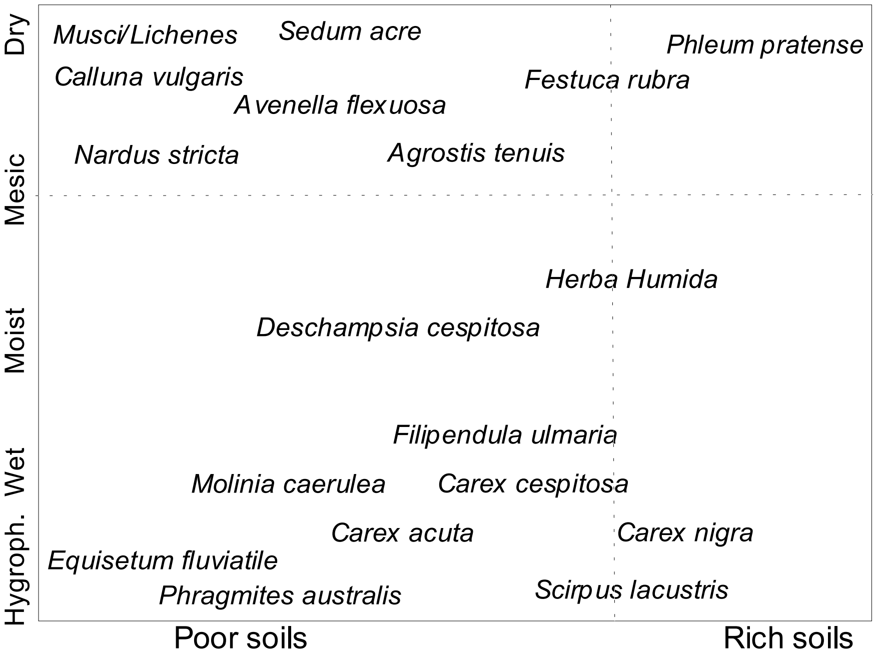

Fig. 32. Ecological scheme of major grassland associations in Karelia (coastal grasslands are excluded)

Associations are named after to their dominant species according the typology set out in this paper. Dotted lines indicate average soil fertility and moisture conditions. Mesotrophic mesophylous environment corresponds to points of intersection

Dry grasslands. As this type accounts for over 80% of all Karelian grassland it will be discussed first. Extensive massifs of dry grassland occur in major agricultural areas such as the Zaonezh'e (Yudina, 2000) and North Ladoga (Lopatin, 1971a). They are quite common in Southern Karelia.

Dry grasslands in Karelia are mainly composed of tall-grass associations dominated by *Phleum pratense* and *Dactylis glomerata*. These two species prevail in all relatively stable dry grassland communities although their flora may easily be divided into a number of ecological types differing according to geological conditions. Valuable grass species were sown in man-made grasslands but the flora of present-day tall grasslands resembles that of cultivated grasslands and poorly accessible sites where no undersowing was carried out. Owing to their semi-artificial origination the status of these grasslands was for a long time under question. Thus, meadow communities making up more than a half of the area of Karelian grassland were omitted from Ramenskaya's monograph (1958) as the author doubted the sustainability of cultivated grasslands. However in 1971 Valentin Lopatin argued that if a sown meadow ecosystem remains unchanged for a long period of time after abandonment it may be considered as natural (Lopatin, 1971b). Recent studies have shown that such meadows are fairly stable and can be regarded as a special type (Znamenskiy, 1999). Communities of fairly common occurrence in the North Ladoga region containing subdominant *Festuca rubra* are sometimes referred to as individual formations.

It should be noted that such tall-grass formations are uncommon in Fennoscandia where soils are generally poor. By contrast, in Karelia they are relatively diverse, productive and consequently of economic value. Also of interest is the fact (Lopatin 1971b) that these meadows suffer from shortage of ground water for twelve out of every fifteen years and are thus transformed into steppe-like ecosystems. Lopatin concentrated on the ecomorphotype of shungite alvars which are distributed on shungite deposits in Zaonezh'e with thin soil cover and characteristic coppices of tree-like juniper (Znamenskiy, 2000).

Communities of *Agrostis tenuis* are floristically and ecologically similar to tall-grasslands. Of common occurrence in Southern Karelia, they are a poor variant of dry grasslands in which tall grasses fail to dominate. *Agrostis tenuis* formations growing on acid soils co-dominating with *Anthoxanthum odoratum* are sometimes described as a separate formation (Lobanova, 1970).

In the regions of Zaonezh'e and North Ladoga *Festuca ovina* forms small patches on rocky outcrops. However, unlike in Sweden where communities of this species are prolific and diverse (Rosén, Borgegård, 1999), they are displaced by tall-grass and *Agrostis tenuis* formations and survive only at the ecological periphery. They can thus hardly rank as communities. In fact these last-mentioned associations can be regarded as transitional to heath grasslands.

Heath grasslands. Xerophylous grasslands on poor soils occur in many parts of Southern Karelia but do not form large massifs anywhere. Examples of heath grasslands are communities dominated by *Nardus stricta* and *Avenella flexuosa*. This last-mentioned was already scarce when Ramenskaya was writing her monograph in 1958.

Today such communities are observed only for short periods in deforested areas. Although grasslands dominated by *Nardus stricta* are rather common on the podsolic soils in southern Karelia and should be considered as a final stage of dry meadows.

Dwarf shrub communities of *Vaccinium* species and *Calluna vulgaris* forming temporary communities on areas of clear fell mainly in Northern Karelia are also classified as heathlands. An extreme case of dry heathland is exemplified by bedrock vegetation composed of *Sedum acre* or various bryophyte and lichen communities.

Moist and wet grasslands are the main subject of Ramenskaya's review (1958). However they are not prolific in either Northern or Southern Karelia. Moreover they have dwindled drastically over the last few decades as paludified hayfields and pastures were the first to be abandoned due to low economic value. They vary significantly in soil moisture from almost dry grassland to semi-mire and semi-aquatic vegetation.

Communities of *Deschampsia cespitosa* make up the most common type of the moist grassland. They are close to mesic grasslands in terms of flora and productivity and are therefore of considerable economic value in areas lacking good dry grassland.

Herb rich communities growing on richer humid soils in the Pudozh district and in Zaonezh'e are sometimes classified as *Humidoherbosa*. In fact they mark a transition to dry grassland communities of tall grasses co-dominated with various herb species.

Monodominant communities of *Filipendula ulmaria* are reported from wetter environments such as springs and temporarily flooded places. They occur throughout Karelia but never form large massifs.

Formations of *Molinia caerulea* are common in Northern and Central Karelia and occur mostly on temporarily flooded lands.

Wet and mire grasslands differ from the moist type not only in their higher moisture content but also in the higher proportion of peat in the soil. Communities of *Carex acuta* that occur mainly along flooded riverbanks and lakeshores seem to be the most common mire-like grassland formation and grow in a variety of environments throughout Fennoscandia. They often merge with communities of *Equisetum fluviatile* (see Hygrophilous vegetation).

In drier soils with low levels of peat communities of *Carex cespitosa* form in lowlands and creek bed depressions but do not form large massifs.

Prolific on peat soils are grasslands dominated by *Carex nigra.* Occupying large areas in Southern Karelia, this sedge community requires richer soils.

Other numerous wet grassland formations on peat soil described by Ramenskaya (1958) are to be regarded as mire vegetation and are thus not discussed in this paper (see Kuznetsov, present volume).

Hygrophylous vegetation. Communities of hygrophytes are not grasslands in the strict sense of the word and are rather far-removed from the mesophytic class. However, as both Shennikov (1941) and Ramenskaya (1958) described them in their reviews let us also briefly survey these communities.

The most common semi-aquatic species occurring throughout Karelia along lakeshores and the White Sea coast is *Phragmites australis*. This reed does not require fertile soil and develops in a variety of environmental conditions. By contrast, *Scirpus lacustris* is restricted to the shallow-water areas of mesotrophic lakes mainly in Southern Karelia. *Typha angustifolia* is occasionally encountered at the northern boundary of its distribution area along the River Vidlitsa and on some lakes in Zaonezhy'e.

Communities of *Equisetum fluviatile* resembling mire ecosystems are widespread on fairly acid soils in shallow water areas and on the shores of lakes and banks of creeks.

Sea coastal grasslands. Primary coastal grasslands occurring under specific soil moisture and salinity conditions in a narrow belt along the White Sea coast form a special type of grassland ecosystem. Sea surf is an important environmental factor for them. Unlike other types of grassland vegetation coastal grassland associations are clearly distinguished from one another and no gradual transition is observed. So far few studies in Karelia have concentrated on this kind of vegetation.

The most common type of halophytic vegetation is the sedge *Carex mackenziei* which in drier environment is replaced by *Juncus gerardi* often co-dominating with *Festuca rubra*. North of Belomorsk communities of *Puccinella maritima* are widespread. In the upper parts of the surf zone associations of *Alopecurus arundinaceus* and *Agrostis gigantea* are also encountered.

Other examples of coastal vegetation include communities of the reed (*Phragmites australis*) growing together with halophytic species such as *Eleocharis uniglumis* and *Bolboschoenus maritimus* which are found in shallow waters and in water-filled hollows and channels.

In the tidal zone vegetation is highly fragmented and made up of individual *Aster tripolium*, *Triglochin maritimus* and various other halophytic species.

Certain temporary communities poor in species such as associations of *Heracleum sibiricum* growing on disturbed soils in Zaonezh'e or *Elytrigia repens* on patches of fertilised soil are not discussed in this section. Such communities are quite short-lived and disappear as soon as the supply of soil nutrients is exhausted. Another example of a short-lived formation is *Chamerion angustifolium* which commonly forms temporary grassland-type communities on areas of forest clearfell and on overgrown farmlands in many parts of Karelia.

Grassland provinces of Karelia. Ramenskaya (1958) distinguished five distinct grassland provinces in Karelia (fig. 33). This remains the only attempt to describe the geography of Karelian grasslands. Each province is briefly described below.

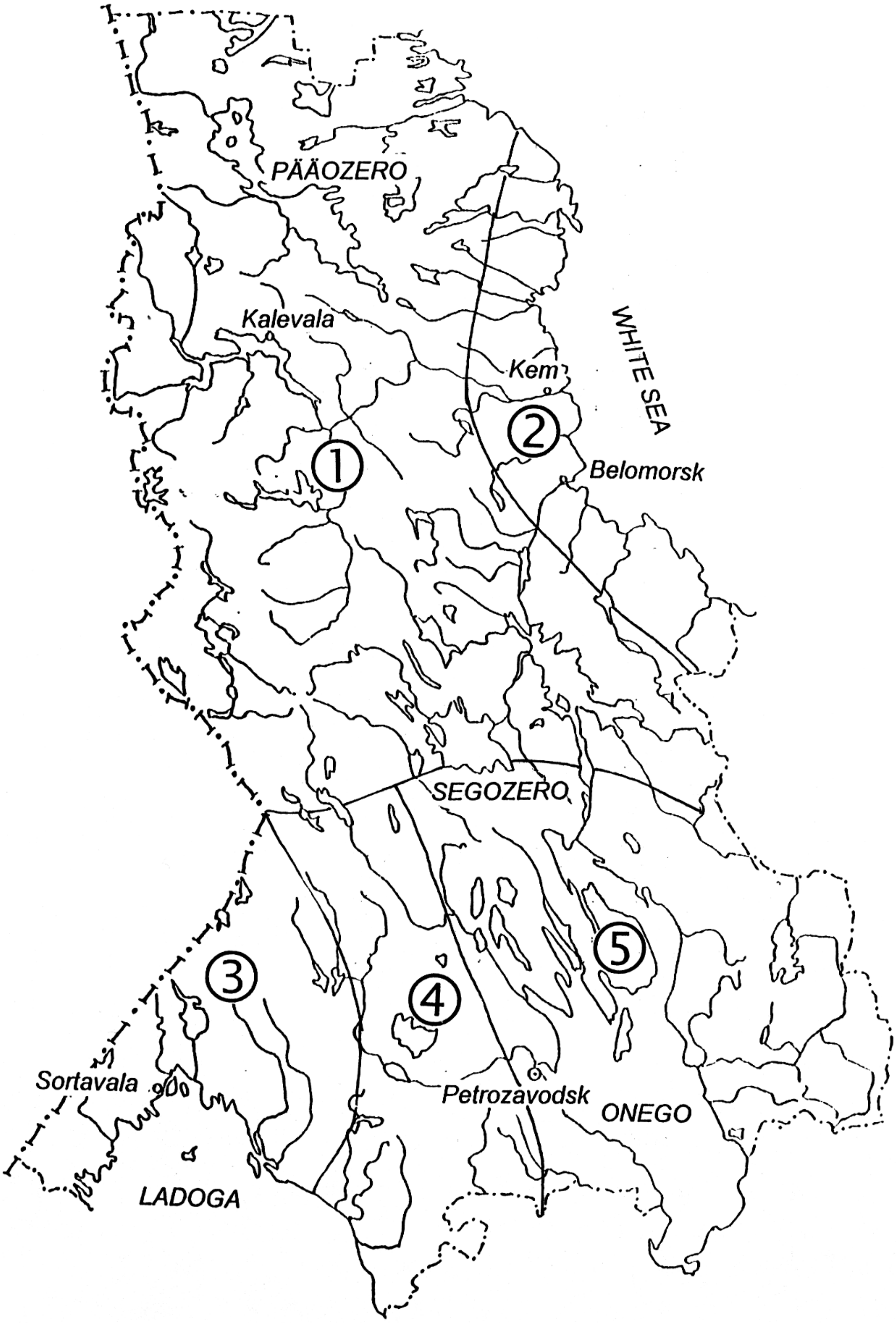

Fig. 33. Map of Karelia grassland provinces (after Ramenskaya, 1958)

1. North-Central province; 2. White Sea province; 3. South-western province; 4. Southern province; 5. South-eastern province

The North-Central province (1) includes the territories of the Louhi, Kalevala, Kem’, Muezerskiy, Belomorsk, Segezha and Kostomuksha administrative districts excluding the White Sea coast. This province is of low agricultural value and grasslands make up only 0.01% of its total area. In spite of the large area of this province it contributes no more than 5% of all Karelian grasslands. It is generally dominated by *Deschampsia cespitosa* in river and lake valleys and by *Agrostis tenuis* in drier environments. Dwarf shrub (*Vaccinium* species or *Calluna vulgaris*) and *Avenella flexuosa* heathlands occur on areas of clearfell in this province. In addition, various types of wet grassland occur in small patches near lakes and rivers.

Of greatest interest in this province are tall-grass (sic!) meadows on the shores of Lake Paanajärvi. They are fairly stable even though they have not been cultivated for some 60 years. These meadows undoubtedly deserve further studies and protection.

The White Sea province (2) extends as a 30–50 km wide strip along the White Sea coast. Grasslands formed of *Deschampsea cespitosa* and *Carex nigra* account for just 0.01–0.02% of the area of the province. Coastal halophytic grasslands occurring only in this region of Karelia contribute substantially to regional diversity. These have already been described above.

The South-western province (3) includes the districts of Lahdenpohja, Pitkaranta and Sortavala (North Ladoga region) as well as parts of the neighbouring districts of Suojärvi and Olonets. This province was second in terms of agriculture only to Zaonezh’e. Grasslands make up about 3% of the total area of the province and account for some 43% of all Karelian grassland. Most of these grasslands are tall-grass meadows but *Agrostis tenuis* and *Herba varia humida* communities also occur, thus indicating a fairly high soil fertility.

Unfortunately the grasslands of Ladoga region have not been studied in sufficient detail. They have been significantly transformed since the last studies were conducted in the mid 20th century (Lopatin, 1971a) and should therefore be re-investigated.

The Southern province (4) includes the districts of Olonets and Pryazha as well as the border zones of adjacent districts in Southern Karelia. The proportion of grassland corresponds with the Karelian average except for the Olonets district where it covers 1.28% of the total territory. Grasslands located in the southern part of the province were studied in detail by Valentina Yudina (Lobanova) (Lobanova, 1971). She described them in terms of dry oligotrophic grasslands and *Deschampsia cespitosa* meadows formed on hayfields and pastures. Ramenskaya (1964) focused on oligotrophic grasslands on peat soils occurring in the northern part of the province.

The South-eastern province (5) covers the districts of Pudozh, Kondopoga and Prionezh’e, the Vepsian national district and the most interesting part of the Medvezh’egorsk district. As the province is geologically heterogeneous its grasslands are fairly diverse. They account for about 40% of all Karelia grasslands. A half of these are located in Zaonezh’e due to the fact that this has long been the best developed agricultural area in Karelia and, indeed, the only area in northern Russian where wheat can be cultivated. High average temperatures (even higher than in North Ladoga region) and fertile soils were conducive to the development of field farming. In the 20th century the proportion of sown land diminished and areas of abandoned lands accumulated. Today grasslands cover 20–25 000 hectares in Zaonezh’e. In many areas highly productive grasses and legumes were undersown. However, cultivation ended quite a long time ago although the structure of these lands remains stable. From their present-day appearance one might easily deceived into believing that these grasslands were of natural origination. In any case Zaonezh’e tall-grass meadows are unique not only to Karelia but also to North Europe.

Elsewhere in the province grasslands are diverse but not extensive. Of interest are the grasslands located in the culturally and historically important Vodlozero region. These grasslands have yet to studied properly.

Non-paludified flooded meadows in the Upper Vodla and Koloda rivers of the Pudozh district are of interest because flooded river valleys are generally typical of East European plains rather than of Fennoscandia. According to the State Land Committee of Karelia in 1998 they extended over just 5 ha in Karelia.

The major part of Karelian grassland studies was performed in this grassland province. During the period 1960-1980 the dynamics of various types of grasslands were being studied at the Bol. Voronovo Field Research Station (see e.g. Zaikova, 1980). Grasslands in Zaonezh’e are now being studied as part of an ecological monitoring programme launched by the Kizhi Open Air Museum (Znamenskiy, 1999; Yudina, 1999, 2000).

Conclusion. To sum up, Karelia grasslands exhibit ecological and phytosociological patterns all of their own. Karelian tall-grasses meadows are not typical of either Fennoscandia or the East European Plain. Unfortunately, the studies of recent years have concentrated on only one region (albeit in great detail), namely, Zaonezhy’e. It is desirable to continue and expand these studies both geographically and ecologically.

3. FLORA AND FAUNA OF TERRESTRIAL ECOSYSTEMS: CHARACTERISTICS AND VARIATION TRENDS

3.1. Vascular plants

3.1.1 The role of protected areas in Karelia's border zone in the conservation of floristic biodiversity

Introduction. Karelia extends over 650 km from latitude 61° N northwards as far as the Arctic Circle. Its flora has been formed by the migration of species from various floristic complexes following the retreat of the most recent glaciation. Analysis of the floristic composition both of the whole of Karelia and of each floristic province (Kravchenko et al., 2000; Kravchenko & Kuznetsov, 2001) has shown that Karelia contains a total of 1631 vascular plant species, 926 of which are aboriginal or archeophytic. The flora of southern Karelia is the most varied in terms of the total number of species present and the prolificacy of aboriginal plants. Many plants occurring close to areal boundaries are rare and should therefore be protected. Listed in the Red Data Book of Karelia (1995) are 205 vascular plant species. In preparing the Red Data Book of East Fennoscandia (Red Data Book…, 1998) the authors revised and extended the lists of species in need of protection. More recently 267 Karelian vascular plant species were classified in accordance with IUCN.

As a result of commercial activities rare species are likely to become less prolific and populations may even be destroyed. The best way to conserve typical and unique ecosystems, as well as rare and endangered plant populations, is to establish strictly protected nature areas (SPNAs). Karelia has a well-developed SPNA network (Hokhlova et al., 2000) which nevertheless fails to represent the entire diversity of Karelian ecosystems. Therefore, over the past few years scientists in Karelia have been conducting large-scale joint studies with the Ministry of the Environment of Finland in order to identify and delineate valuable territories and present convincing arguments in favour of establishing new SPNAs.

Of great significance as a potential SPNA is an approximately 50 km wide segment of the Karelian-Finnish border extending along longitude 31° E on the Karelian side of the border. As well as being an excellent experimental area for the biogeographic study of East Fennoscandia this area incorporates a number of territories vital for the conservation of regional biodiversity as well as of the south, mid and north-taiga subzones (Yurkovskaya, 1993). The segment extends across five biogeographic provinces in Fennoscandia (Mela & Cajander, 1906) described as floristic provinces by Kravchenko & Kuznetsov (2001). Located in this territory is the Baltic Sea-White Sea watershed which is dominated by landscapes containing a rugged relief of denudation-tectonic genesis and which has given rise to a variety of habitats and a diverse vegetation cover. Most of the territory has always been sparsely populated and as a consequence of state border regulations there have been no permanent settlements here during the past forty years. Large fragments of undisturbed landscapes containing primeval forests, natural mires and lakes bearing no signs of pollution or eutrophication have survived. South of 63° N the territory has long been developed by man and exhibits a variety of anthropogenic habitats and secondary communities.

Northern Priladozhye (the southernmost part of Karelia's border zone) and the Lake Paanajärvi area (northernmost portion) have been studied botanically over some 150 years and have provided a source of extensive floristic information which has been presented in dozens of publications. In the 1970s scientists began to study the vegetation cover in the area of Kostomuksha but because of poor roads, border regulations and the sparse population practically nothing was known of the vegetation of the remainder of the border zone until botanical research began there ten years ago. With the exception of the Priladozhye and Lake Paanajärvi areas, almost the whole of the border zone is of lesser interest to botanists due to its watershed location and the predominance of oligotrophic habitats on felsic granite gneisses and poor sand. This compares with territories with more varied biotopes and diverse flora, containing eutrophic mires, mafic and carbonate bedrock exposures, motley-grass and nemoral forests and extrazonal communities.

On the basis of the results of multi-disciplinary studies of ecosystems of the entire border zone carried out during 1994-1999 by the Karelian Research Centre, RAS, and supported by the Ministry of the Environment of Finland, a proposal was put forward to establish a number of protected areas (Sazonov & Kravchenko, 1996 et al.).

The whole zone on both sides of the border, which stretches from the Baltic Sea to the Barents Sea, is now known as the Green Belt of Fennoscandia. Proposals to include it in the UNESCO World Natural and Cultural Heritage List have been made and large-scale studies have been conducted in Russia, Finland and Norway in order to present arguments in favour of the establishment of various types of protected areas. Located in the Karelian part of the Green Belt of Fennoscandia are a number of existing and proposed SPNAs (Fig. 34). As vascular plants have been studied in all of these over the past twenty years their contribution to the floristic diversity of Karelia may now be assessed.

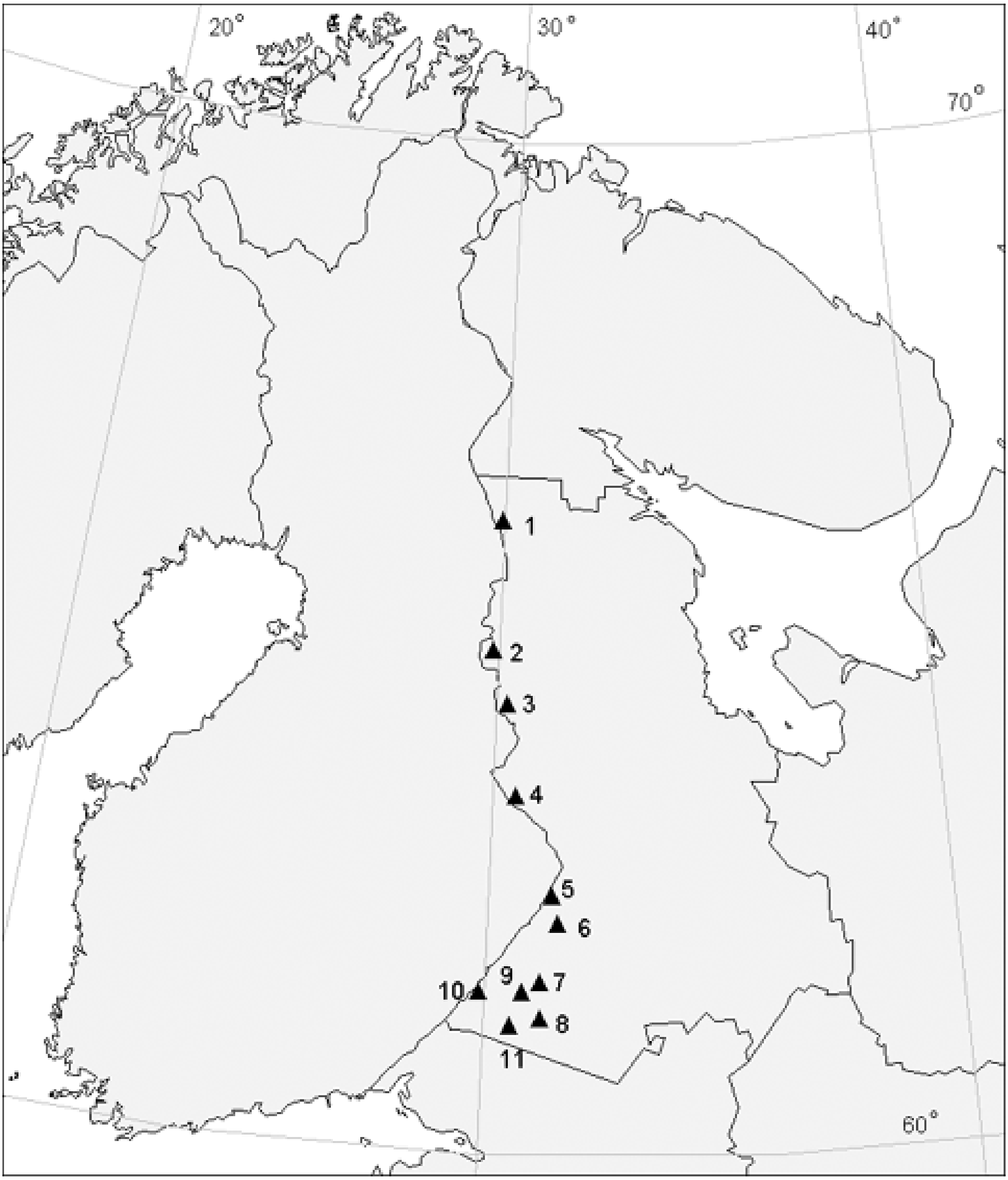

Fig. 34. Existing and planned PAs:

1. Paanajärvi National Park, 2. Kalevala proposed National Park (PNP), 3. Kostomuksha Strict Nature Reserve, 4. Tuulos PNP, 5. Koitajoki PNP, 6. Tolvajärvi Landscape Reserve, 7. Ladoga Skerries PNP, 8. Sortavala Botanical Reserve, 9. Valaam Archipelago Nature Park, 10. Iso-Iijärvi Landscape Reserve, 11. Zapadny Archipelago Landscape Reserve

Materials and methods. Flora was studied by the traverse route method and all types of habitats were examined in each territory. The plants sampled are kept in the Forest Research Institute Herbarium, Karelian Research Centre, RAS (PTZ). The goal of this study is to analyse the prolificacy of rare and endangered vascular plant species listed in the Red Data Books of Russia (1988), Karelia (1995) and East Fennoscandia (Red Data.., 1998) in existing and proposed SPNAs in the Karelian part of the Green Belt of Fennoscandia and to assess their role in the conservation of regional floristic biodiversity. Available literature, archives and herbaria were analysed together with the results of the floristic studies carried out in Karelia over the past few years.

Results. The extent of study of vascular plants in existing and proposed SPNAs in the border zone of Karelia (Fig.34) varies from area to area. Information on the flora of each SPNA and evidence for the occurrence of Red Data Books species is presented below (Table 11).

The Zapadny Archipelago Landscape Reserve (total area 19527 ha, land area 393 ha, established 1996). Until recently very little was known about the flora of the archipelago which lies in the western part of Lake Ladoga, and only limited evidence was available concerning the occurrence of dozens of species (Rasanen, 1944; Hiitonen, 1946). The results of our studies undertaken in 1993 show that the archipelago has a population of 334 vascular plant species. Lists of species for six of the seven largest islands are now available (Kravchenko & Kryshen, 1995). As each of the islands was visited for only a short time and Kugrisaari, one of the largest islands, has not been studied at all, some species new to each specific island and even to the whole archipelago are still likely to be found. The archipelago is populated by 18 Red Data Book species (Table 11), some of which belong to the arctalpine group and occur at the southernmost limits of their distribution areas.

The Iso-Iijärvi Landscape Reserve (area 5778 ha, established 1995). We do not know of any publication dealing with the flora of this area. It appears that owing to the paucity of its flora, especially in comparison with the Lake Ladoga skerries, this territory had until recently not attracted the attention of botanists. In 1994 we conducted a feasibility study concerning the establishment of a reserve there. We concentrated solely on the eastern part of the reserve (east of Lake Pieni-Iijärvi) where a total of 325 vascular plant species were found. Interestingly, *Chimaphila umbellata*, which is seldom encountered in Karelia, was reported at various sites on the shore of Lake Iso-Iijärvi in communities formed during primary succession after the water level of the lake had dropped by several metres. To date only five Red Data Book species have been identified in the reserve (Table 11).

The Valaam Archipelago Nature Park (total area 24 700 hectares, land area 3600 hectares, established 2000). The park covers the Valaam unique historical and nature-landscape territory which previously contained the Open Air Museum of History, Architecture and Nature and a forest reserve. Floristic studies have been conducted in Valaam since the mid 19th century and data on some of the archipelago's plants are presented in numerous publications. However, it was not until 1925 (Hulkkonen, 1925) that a relatively long list of species appeared. Many species reported from Valaam before the Second World War are listed in the Atlas of Vascular Plant Distribution in North Europe (Hulten, 1971). A fairly complete list of plants known in the archipelago was published by Pobedimova and Gladkova (1966) and more recent evidence for new species has been discussed elsewhere (Ronkonen & Kravchenko, 1983; Kravchenko, 1988; Ecosystems of Valaam .., 1989). Over the past decade further information on the flora of Valaam has been obtained and certain species previously unknown to the archipelago have been found. However, the results of these studies have yet to be summarised. The park has at least 590 vascular plant species (in addition to introduced plant species which grow there in great abundance). The finding of 61 Red Data Book species (Table 11) indicates once again that this SPNA is of considerable floristic valuable and needs to be preserved. Some species such as *Platanthera chlorantha, Corydalis intermedia, Cotoneaster integerrimus* and *Potentilla neumanniana* do not occur in other protected areas in Karelia.

The proposed Ladoga Skerries National Park (area approx. 84 000 ha) displays a unique diversity of biotopes. Botanical studies have been conducted here since the mid 19th century. Finnish botanists have published numerous papers describing the floristic patterns of specific localities and the occurrence of individual species. Available floristic data was summarised and analysed in the early 20th century (Linkola, 1916, 1921). The distribution of species in the park is clearly presented in an atlas made by E. Hultén (1971) but the author only made use of data obtained by Finnish botanists before the Second World War. We have been carrying out floristic studies in various parts of the park since 1984 but the data published covers only one locality (Kravchenko et al., 2000).

After a break of some fifty years Finnish botanists and students have over the past decade resumed studies here. A paper dealing with all the protected species ever recorded in the park has recently appeared (Heikkila et al., 1999). The study of specific sites long associated with certain rare and endangered vascular plants has shown that populations of these species are stable. Most species previously collected here were found again at each respective locality (Vasari, 1998; Heikkilä et al., 1999a; Savola, 1999). The preliminary list for the park consists of about 750 species. As land accounts for about a half of the park's area (approx. 40 000 ha) the floristic diversity of the park is abnormally high by Karelian standards. The park contains 101 Red Data Book species (Table 11). This territory is of very great importance for the conservation of vascular plant diversity not only of the Karelian border zone but also of the whole of Karelia and, indeed, East Fennoscandia.

The Sortavala Botanical Reserve (area 100 ha; founded 1978) was established in order to preserve Karelia's largest collection of introduced arboreal plants including no less than 109 species, varieties and forms (Andreyev & Kuchko, 1990). The wild flora of the reserve is also highly diverse. In spite of its proximity to Sortavala the territory has not been visited by Finnish botanists and only a few species have been sampled. During the course of our

Table 11

Occurrence of vascular species listed in the Red Data Books of Russian Federation (1988), Karelia (1995) and East Fennoscandia (1998) in the Nature Protection Areas along Russian-Finnish border (IUCN categories shown*)

Species	Nature Protection Area											Red Data Book		
	West Archipelago	Iso-Iijärvi	Valaam	Ladoga Skerries	Sortavala	Tolvajärvi	Koitajoki	Tuulos	Kostomuksha	Kalevala	Paanajärvi	Russian Federation	Karelia	East Fennoscandia
Woodsia alpina (Bolt.) S. F. Gray			+	+					+		+		3	3
Woodsia glabella R. Br.											+		3	3
Cystopteris dickieana R. Sim.	+			+							+		3	3
Gymnocarpium jessoënse (Koidz.) Koidz.											+		2	2
Gymnocarpium robertianum (Hoffm.) Newm.				+							+		2	3
Polystichum lonchitis (L.) Roth											+		0	0
Asplenium ruta-muraria L.				+							+		3	3
Asplenium septentrionale (L.) Hoffm.	+		+	+									4	4
Asplenium viride Huds.				+							+		4	3
Botrychium boreale Milde	+		+	+							+		3	3
Botrychium lanceolatum (S. G. Gmel.) Ångstr.				+						+	+		4	4
Botrychium matricariifolium A. Br. ex Koch			+	+									2	2
Botrychium multifidum (S. G. Gmel.) Rupr.				+			+		+	+	+			3
Botrychium simplex E. Hitchc.				+								1	0	0
Botrychium virginianum (L.) Sw.				+									2	2
Ophioglossum vulgatum L.				+			+							3
Diphasiastrum alpinum (L.) Holub										+	+		4	
Isoëtes echinospora Durieu		+	+	+		+	+	+	+	+	+	2	4	
Isoëtes lacustris L.		+	+	+		+	+	+	+	+	+	2	4	
Sparganium glomeratum (Laest.) L. Neum.		+	+	+				+	+	+				3
Agrostis clavata Trin.										+			3	3
Brachypodium pinnatum (L.) Beauv.				+									3	3
Cinna latifolia (Trev.) Griseb.				+									3	3
Elymus fibrosus (Schrenk) Tzvel.											+		2	2
Elymus kronokensis (Kom.) Tzvel.											+		2	2
Elymus mutabilis (Drob.) Tzvel.											+			1
Festuca sabulosa (Anderss.) Lindb. fil.	+			+									3	3
Hierochloë australis (Schrad.) Roem. & Schult.			+	+									3	3
Hierochloë hirta (Schrank) Borb.			+	+	+									3
Lolium remotum Schrank				+										0
Poa lapponica Prokud.	+		+											2
Carex adelostoma V. Krecz.											+		3	3
Carex atherodes Spreng.				+				+			+			3
Carex bohemica Schreb.				+										3
Carex contigua Hoppe			+	+									3	
Carex glacialis Mackenz.											+		4	2
Carex heleonastes Ehrh.											+			4
Carex jemtlandica (Palmgr.) Palmgr.											+		4	1
Carex laxa Wahlenb.											+	3	2	2
Carex livida (Wahlenb.) Willd.									?	+	+	3	4	+
Carex media R.Br.											+		3	3
Carex muricata L.	+		+	+									3	3
Carex norvegica Retz.			+	+							+		1	
Carex parallela (Laest.) Sommerf.											+		0	0
Carex rupestris All.											+		3	3
Carex scandinavica E.W. Davies				+										3
Carex tenuiflora Wahlenb.										+	+			3
Carex vulpina L.								+					1	1
Eleocharis mamillata Lindb. fil.				+			+		+		+			3
Eriophorum brachyantherum Trautv. & C. A. Mey.											+		4	3
Rhynchospora fusca (L.) Ait. fil.				+								3	3	3

Species	Nature Protection Area											Red Data Book		
	West Archi-pelago	Iso-Iijär-vi	Vala-am	Lado-ga Sker-ries	Sor-ta-vala	Tolva-järvi	Koita-joki	Tuu-los	Kosto-muk-sha	Kale-vala	Paa-najä-rvi	Rus-sian Fede-ration	Kare-lia	East Fenno-scandia
Scirpus radicans Schkuhr				+									3	3
Juncus bulbosus L.				+		+	+	+	+	+				4
Juncus triglumis L.											+		3	3
Luzula spicata (L.) DC.											+		0	0
Allium schoenoprasum L.				+										3
Allium strictum Schrad.			+	+	+								3	3
Gagea lutea (L.) Ker-Gawl.				+	+								4	4
Cypripedium calceolus L.				+							+	3	4	4
Calypso bulbosa (L.) Oakes											+	3	3	3
Dactylorhiza cruenta (O. F. Muel.) Soó			+							+			3	3
Dactylorhiza lapponica (Laest.) Soó											+			1
Dactylorhiza traunsteineri (Saut.) Soó						+		+	+	+	+	3	4	
Epipogium aphyllum Sw.				+							+	4	3	3
Malaxis monophyllos (L.) Sw.			+	+									2	2
Neottia nidus-avis (L.) Rich.			+	+	+								3	3
Platanthera chlorantha (Cust.) Reichenb.			+										2	2
Salix acutifolia Willd.			+										4	
Salix pyrolifolia Ledeb.											+		2	1
Salix reticulata L.											+			3
Salix triandra L.											+		3	3
Myrica gale L.				+								2	1	2
Ulmus glabra Huds.			+	+									3	3
Humulus lupulus L.			+	+					+				3	3
Rumex maritimus L.			+	+										3
Agrostemma githago L.				+										0
Arenaria pseudofrigida (Ostenf. et Dahl) Juz. ex Schischk.											+		3	3
Cerastium alpinum L.	+		+	+	+						+		3	
Dianthus arenarius L.			+	+									3	3
Gastrolychnis angustiflora Rupr.											+		1	0
Gypsophila fastigiata L.											+		2	2
Minuartia verna (L.) Hiern				+									0	3
Myosoton aquaticum (L.) Moench				+									3	3
Psammophiliella muralis (L.) Ikonn.									+					4
Silene nutans L.	+		+	+									3	
Silene tatarica (L.) Pers.											+			3
Steris alpina (L.) Šourkova				+							+		3	3
Stellaria calycantha (Ledeb.) Bong.										+	+		3	3
Batrachium eradicatum (Laest.) Fries											+		4	
Batrachium trichophyllum (Chaix) Bosch									+		+		4	3
Ficaria verna Huds.				+									3	3
Ranunculus cassubicus L.			+	+	+								3	
Ranunculus hyperboreus Rottb.											+		3	3
Thalictrum aquilegifolium L.			+	+	+									3
Corydalis intermedia (L.) Merát			+										2	2
Arabis alpina L.											+		2	
Cardamine parviflora L.	+		+										3	3
Draba cinerea Adams				+							+		3	3
Draba hirta L.											+		3	3
Draba nemorosa L.	+		+	+										4
Erophila verna (L.) Bess.	+		+	+										3
Jovibarba sobolifera (Sims) Opiz				+	+								3	
Tillaea aquatica L.				+					+				3	3
Saxifraga adscendens L.			+	+									3	3
Saxifraga aizoides L.											+		3	3
Saxifraga cespitosa L.	+		+	+	+									3

End. table 11

Species	Nature Protection Area											Red Data Book		
	West Archipelago	Iso-Iijärvi	Valaam	Ladoga Skerries	Sortavala	Tolvajärvi	Koitajoki	Tuulos	Kostomuksha	Kalevala	Paanajärvi	Russian Federation	Karelia	East Fennoscandia
Saxifraga hirculus L.											+			3
Saxifraga nivalis L.	+		+	+	+						+			3
Agrimonia eupatoria L.				+										3
Agrimonia pilosa Ledeb.				+										3
Alchemilla hirsuticaulis Lindb. fil.			+											4
Alchemilla murbeckiana Bus.			+	+										4
Alchemilla plicata Bus.				+										3
Alchemilla propinqua Lindb. fil. ex Juz.								+						3
Cotoneaster x antoninae Juz. ex Orlova			+	+										4
Cotoneaster integerrimus Medik.			+										2	?
Padus borealis Shubel.											+			4
Potentilla crantzii (Crantz) G. Beck. ex Fritsch			+								+		2	2
Potentilla neumanniana Reichenb.			+										0	0
Potentilla nivea L.											+			2
Potentilla chamissonis Hult.											+		2	2
Sibbaldia procumbens L.											+		0	1
Sorbus gorodkovii Pojark.										+	+			4
Astragalus frigidus (L.) A. Gray											+		3	3
Astragalus subpolaris Boriss. & Schischk.			+								+		3	3
Oxytropis sordida (Willd.) Pers.											+		3	3
Geranium bohemicum L.				+									3	3
Geranium robertianum L.				+	+									3
Polygala comosa Schkuhr	+												2	1
Polygala vulgaris L.				+									3	3
Callitriche hermaphroditica L.				+							+			3
Hypericum perforatum L.	+		+	+	+								3	3
Elatine orthosperma Dueben				+									2	2
Elatine triandra Schkuhr				+									3	3
Viola rupestris F.W. Schmidt			+	+	+		+				+			4
Viola persicifolia Schreb.	+		+	+									3	3
Peplis portula L.				+									3	3
Epilobium alsinifolium Vill.											+		3	3
Epilobium davuricum Fisch. ex Hornem.											+		3	3
Epilobium hornemannii Reichenb.									+	+	+		3	
Epilobium laestadii Kytov.											+			2
Myriophyllum sibiricum Kom.				+							+		3	
Myriophyllum verticillatum L.			+	+					+				3	
Angelica archangelica L.											+		3	3
Oenanthe aquatica (L.) Poir.			+										4	4
Pimpinella major (L.) Huds.	+		+										3	3
Chimaphila umbellata (L.) W. Barton		+	+	+									3	3
Pyrola norvegica Knab.											+			4
Hypopitys monotropa Crantz			+	+		+							3	3
Loiseleuria procumbens (L.) Desv.											+		3	
Phyllodoce caerulea (L.) Bab.											+		3	3
Androsace septentrionalis L.				+							+		2	2
Primula stricta Hornem.											+		3	3
Gentianella amarella (L.) Boern.				+							+			4
Gentianella lingulata (Agardh) Pritchard			+	+						+	+			4
Cuscuta epilinum (L.) L.				+									0	0
Cuscuta europaea L.				+									3	
Polemonium acutiflorum Willd. ex Roem. & Schult.											+		1	1
Hackelia deflexa (Wahlenb.) Opiz			+	+							+		4	3
Myosotis decumbens Host											+		3	2
Myosotis ramosissima Rochel ex Schult.			+										2	2

Species	Nature Protection Area											Red Data Book		
	West Archipelago	Iso-Iijärvi	Valaam	Ladoga Skerries	Sortavala	Tolvajärvi	Koitajoki	Tuulos	Kostomuksha	Kalevala	Paanajärvi	Russian Federation	Karelia	East Fennoscandia
Dracocephalum ruyschiana L.				+									3	
Origanum vulgare L.			+	+	+								3	3
Thymus subarcticus Klok. & Shost.											+		2	2
Limosella aquatica L.				+										4
Veronica fruticans L.											+		2	2
Veronica spicata L.			+	+									3	3
Pinguicula alpina L.											+		3	3
Pinguicula villosa L.									+	+	+			4
Littorella uniflora (L.) Aschers.									+				4	2
Galium odoratum (L.) Scop.			+										3	3
Galium trifidum L.			+	+		+	+			+	+			4
Valeriana sambucifolia Mikan fil.			+			+				+	+			4
Campanula cervicaria L.	+		+	+										3
Campanula latifolia L.				+			+						4	4
Campanula trachelium L.			+	+	+								4	
Lobelia dortmanna L.		+		+		+	+	+	+	+	+	3	4	
Aster sibiricus L.											+		0	0
Carlina biebersteinii Bernh. ex Hornem.				+									3	3
Cicerbita alpina (L.) Wallr.											+		3	4
Crepis biennis L.				+										4
Crepis nigrescens Pohle				+							+			3
Erigeron decoloratus Lindb. fil.											+			3
Eupatorium cannabinum L.			+	+									3	3
Inula salicina L.			+	+							+			3
Mycelis muralis (L.) Dumort.				+									3	3
Total number of the species on the protected area	334	325	590	ca. 750	329	368	339	341	395	429	ca. 550			
Number of red listed species	18	5	61	101	15	8	10	9	17	20	97			
Area of protected area / 1000 ha	0.8**	4	3.6*	45*	0.1	42	31	80	47	100	104			

* Status of species according the IUCN categories: 0(Ex) – extinct or probably extinct, 1(E) – endangered, 2(V) – vulnerable, 3(R) – rare, 4(I) - indeterminate.

** = land only.

floristic study of the reserve which began in 1978 we identified a total of 329 vascular plant species (Kravchenko et al., 1997), a very high number for such a small area in the taiga zone. The reserve is now known to contain 15 Red Data Book species (Table 11). In the event of the Ladoga Skerries National Park being established this reserve will be decommissioned and become part of the Ladoga strictly protected zone.

The Tolvajärvi Landscape Reserve (area 41 900 ha, established 1995). The first attempts to briefly survey the area were made as early as 1915–1916 (Linkola, 1916, 1921, 1931). We have visited the reserve many times since 1990 collecting materials for a feasibility study. The first results of our research have recently been published (Kravchenko, 1995). In 1998 a more complete annotated list of species incorporating the 1995–1997 findings appeared (Kravchenko, 1998, manuscript). During 1998–2000 various new species were found. These included *Hypopitys monotropa* which is seldom encountered at this latitude. The reserve has a total of 368 species although only eight of these are listed in the Red Data Books (Table 11).

The proposed Koitajoki National Natural Park (area 30 000 ha). Until recently practically nothing was known of the vegetation cover of the Koitajoki river valley. Our studies conducted in 1995 and 1998 were restricted mainly to the most accessible eastern part of the park. An annotated list of the vascular plants so far identified has been drawn up (Kravchenko et al., 1998, manuscript). In all we found 339 species (Kravchenko & Sazonov, 2000, with supplements), ten of which are included in the Red Data Books (Table 11).

In accordance with a project directed by Rosgiproles in 1997–1998, the Koitajoki National Natural Park will incorporate a segment of the Koitajoki river valley, which stretches as far as the state border, as well as the area covered by the Tolvajärvi Landscape Reserve.

The proposed Tuulos National Natural Park (area approx. 36 000 ha). Until recently almost nothing was known of the flora of the Tuulos area although in 1896 and again during the Second World War various Finnish botanists (Jalas 1948; Erkamo, 1949) conducted studies there. During our brief visits to the park in 1994 we only managed to study the outskirts of Koroppi, Tulevaara and Tuulos. Thus, the list of species presented by Kravchenko and co-workers (Kravchenko et al.,1997a) is far from complete. Including the findings reported in 2000 which incorporate certain species rare in this part of Karelia, e.g. *Carex atherodes* and *C. vulpina* (the latter was known earlier only from the southeasternmost part of Karelia, Ramenskaya, 1983), the reserve is now believed to contain a total of 341 vascular plant species. Nine of these are described in the Red Data Books (Table 11).

The Kostomuksha Strict Nature Reserve (area 47 659 ha, established 1983). The reserve became a part of Finnish-Russian Friendship Park in 1989. Before that the area had been briefly visited once by a Finnish botanist in the late 19th century (Wainio, 1878). A floristic inventory was undertaken after the establishment of the reserve. In all, 395 vascular plant species have been found (Kravchenko & Belousova, 1990; Kravchenko & Kashevarov, 1997; Kravchenko, 1997). So far our studies have not yet covered the western part of the reserve which has been most developed by man and contains a number of old Karelian villages. As this area is still significantly affected by human activities (frontier posts and various technical facilities), new plants, especially alien species, are likely to be found here. Seventeen Red Data Book species (Table 11) including *Tillaea aquatica*, *Littorella uniflora* etc., have been reported. These are the northernmost recordings of the two species in Karelia.

The proposed Kalevala National Park (area approx. 100 000 ha). Until recently no floristic information had been collected from this area. During 1996–1998 we studied almost the whole area of the proposed park excepting its northwestern and western parts (between Lake Nizhnyaya Lapukka and the state border). The first floristic data for the park was published in the form of an annotated list (Kravchenko et al., 1998c); the flora was characterised in general terms Kravchenko et al., 1998a,b) and the composition of several local flora was described (Kravchenko et. al, 2000). 429 species are now known from the park. However, since the area in question is so extensive it would be wrong to suggest that we know everything about its flora. This is borne out by studies conducted in 2000 which revealed many new species including the interesting finds of *Diphasiastrum alpinum* and *Geranium palustre* (the northernmost known site in Karelia) close to the border. Twenty Red Data Book species (Table 11), including *Stellaria calycantha*, were found here at their southernmost known locations in Karelia.

The Paanajärvi National Park (area 104 371 ha, established 1992) has been studied in detail with floristic research beginning as early as the mid 19th century. Most of the data collected concerns the western part of the park, especially the Paanajärvi lake valley. Extensive floristic lists of the area were published by E. Wainio (1878), A. Auer (1944) and M. Kotilainen (1951). During the Second World War the Olanga river valley was studied and an annotated list of species published (Soyrinki, 1956). A comprehensive presentation of floristic data for the park was published in the ‘Atlas of Vascular Plant Distribution in North Europe’ (Hultén, 1971). After break of some 45 years a new stage of floristic research began in 1988. Since then the park has been visited several times by Russian and Finnish botanists and available floristic data from Mount Nuorunen and its environs has been published along with data concerning a number of local flora from the Lake Paanajärvi-River Olanga valley, (Kravchenko et al, 1995; Kravchenko et. al, 2000). A general list of vascular plants (Kravchenko & Kuznetsov, 1993, manuscript) consisting of some 550 taxa has been drawn up (Kravchenko & Kuznetsov, 1993; Kuznetsov & Kravchenko, 2000). As the number of taxa known from the area has increased and our understanding of many taxa considerably improved over the past few years the herbaria collected from the park and kept in Finland need to be revised. Our floristic knowledge of the park is still incomplete as is amply demonstrated by the fact that about twenty species not previously known from the area have recently been found. Thus, for example, *Epipogium aphyllum* (the first recording of this species in the Karelian part of the *Regio kuusamoënsis* province) is reported in 2000 close to Lake Iso-Sieppijärvi. In all, ninety-seven Red Data Book species (Table 11) have been identified in the park. This is only slightly less than for the proposed Ladoga Skerries Park.

Conclusion. The protected areas located in the border zone of Karelia differ appreciably from one another in terms of plant species diversity. The total number of vascular plant species present varies from 325 (Iso-Iijärvi Landscape Reserve) to 750 (proposed Ladoga Skerries National Park). The existing and proposed SPNAs are floristically representative of the biogeographic provinces in which they are located.

Altogether, 186 Red Data Book vascular plant species, i.e. 63% of the total number (298) known to Karelia, are now known to occur in the protected areas situated in the border zone of Karelia (Table 11). The number of Red Data Book species in individual SPNAs varies from 5 (Iso-Iijärvi) to 101 (Ladoga Skerries), suggesting that each protected area contributes to regional biodiversity in its own way. The number of Red Data Book species occurring in SPNAs depends on their area, the diversity of biotopes present and the degree of anthropogenic transformation.

The Paanajärvi National Park is of unique importance for the conservation of northern species. It hosts the entire flora of the Karelian part of *Regio kuusamoënsis* province, including 97 protected species. Indeed, it is the sole location of many Karelian protected species.

The number of protected species in the SPNAs of central Karelia low, i.e. between eight and twenty, and the flora of the region as a whole is limited. Boreal species form widespread tracts while southern and northern species are scarce.

The largest number of Red Data Book species (101) was reported from the proposed Ladoga Skerries National Park. Many southern species occurring there are not encountered in other SPNAs or in other parts of Karelia. Therefore, it is of the utmost importance that this park be established as soon as possible.

Further floristic studies need to be conducted and the monitoring of populations of rare species should be initiated in all existing and proposed SPNAs.

3.1.2. Intraspecific diversity of pine and spruce

The forests of East Fennoscandia form part of the taiga zone. The species composition of forest ecosystems is relatively simple with two to three or even one species dominating over vast territories. However, since these species are spread over large areas containing a wide variety habitats they may be differentiated at interpopulation and cenotic (forest type) levels. As these species possess specific biological characteristics of their own they are also highly diverse at the intrapopulation level.

Thus, in spite of the extremely low species diversity of taiga forests, the intraspecific variation of major forest-forming species is high enough to maintain the stability of forest ecosystems. It is clear that a study of their intraspecific diversity should be carried out in conjunction with the inventory, assessment and conservation of species biodiversity.

Coniferous forests cover 89% of Karelian land area. There are two major forest-forming species: Scots pine (*Pinus sylvestris* L.) and Finnish spruce (*Picea* x *fennica* (Regel) Kom.) which is the spontaneous hybrid between *Picea abies* Karst. and *Picea obovata* Ledeb. (Pravdin, 1975; Scherbakova, 1975; Bobrov, 1978). The study of their intraspecific variation is of importance for the development of methods of maintaining the stability of forest communities and the diversity of forest ecosystems in the region.

Scots pine (*Pinus sylvestris* L.). Pine stands cover 64% of the forested area of Karelia. The composition of forests varies considerably from one province to another. The north-taiga subzone is dominated by pine (76%) while deciduous trees make up just 4%. In the mid-taiga subzone deciduous species account for about 20% of forested area, the rest of the subzone being shared almost equally between pine and spruce.

Scots pine grows in various environments throughout a vast continuous intrazonal area, suggesting that its intraspecific variation reserves are large. The continuity of its habitat together with a good dispersal of its pollen and seeds contributes to gene migration and species integrity. In the absence of well-defined mountain relief, great distances are the main factor responsible for the isolation of populations. Scots pine is a classic example of the continuous geographic variability of population systems. Its genetic structure, phenotypic characters and properties change gradually from north to south with changing photoperiod and other macroclimatic parameters.

G. M. Kozubov (1962, 1963) studied the intraspecific variation of Scots pine in Karelia and in the Kola peninsula. He identified several forms of Scots pine differing in the habit of the crown and the colour of the anthers. He described the following variants: 1) the subspecies *Pinus sylvestris ssp. lapponica* Fr. with two varieties, *var. prostrata mihi* and *var. umbelifera mihi,* which grow in the Kola peninsula and in northern Karelia; 2) pyramidal (*f. pyramidalis* Bessn.) and cypress-like (*f. cupressoides mihi*) forms that mainly occur in the transition zone of Lapland pine and typical pine; 3) bog (*var. nana* Pall.) and lithic (*var. saxicola* Hilitzer) varieties growing in both the Lapland pine and typical pine zones; 4) red-anthered (*f. erythranthera* Sanio) and yellow-anthered (*f. sulfuranthera*) forms. The commercial and selection value of the above forms and varieties was estimated.

The 1990s saw a rising interest in the population-genetic aspects of modern sylviculture in Karelia. A comprehensive study of the intraspecific variation of Scots pine was launched in order to throw light on the regional population structure of the species and to provide a scientific basis for the conservation and improvement of its gene pool. In the initial phase attention was focused on intraspecific variations in the morphological characters of the generative organs of pines that depend on tree genotype rather than ecological factors. Thirteen natural Scots pine stands in Karelia and in the Murmansk, Arkhangelsk and Vologda regions were studied. The individual level of diversity of the morphological characters of cones and seeds (CV = 11.57–35.39%) was found to be higher than their corresponding endogenic (CV = 7.14–31.48%) and ecological-geographic (CV = 6.88–25.61%) levels (Table 12).

Table 12

Intraspecific variation of cone and seed parameters of Scots pine

Characters	Forms of variation (CV cp, %)			Recurrence coefficient (R cp)
	Endogenic	Individual	Geographic	
Apophysis	–	34.30 ± 0.49	14.34 ± 2.03	–
Cone length	8.12 ± 0.36	13.20 ± 0.23	7.86 ± 1.23	0.74 ± 0.016
Cone diameter	7.14 ± 0.25	11.57 ± 0.16	6.88 ± 1.02	0.74 ± 0.016
Cone mass	18.84 ± 0.54	33.31 ± 0.28	25.61 ± 3.48	0.71 ± 0.016
Mass of 1000 seeds	–	20.60 ± 0.40	16.63 ± 2.71	–
Seed length	7.41 ± 0.28	12.61 ± 0.20	7.38 ± 1.21	0.68 ± 0.14
Seed yield	31.48 ± 0.67	35.39 ± 0.38	16.89 ± 1.87	0.48 ± 0.12

All the characters are highly heritable in a broad sense (R = 0.68–0.74) and display low to medium intercorrelation in populations. Obviously, the morphological characters of cones and seeds are highly determined genetically and can be used in population studies.

Variations in the morphological characters of the generative organs of pines indicate that in Karelia pine is poorly differentiated both ecologically and geographically. However, the Scots pine stands studied were found to differ in the quantitative characters of the generative organs. These differences seem to be due to the nature and climate of the region, and indicate that *Pinus sylvestris* is phenotypically and genetically heterogeneous in the study area.

The population structure of Scots pine was studied in order to estimate the differentiation level of the species in Karelia. It should be noted that the populations of most tree species, including Scots pine, are in spatial terms rather poorly isolated and have indistinct boundaries. As it is difficult to analyse intraspecific differentiation by studying individual characters an attempt was made to shed light on the population structure of pine and to compare all the characters of the stands through the use of multivariate statistical models, such as calculation of Machalanobis' generalised distance (D^2), as well as cluster, factor and discriminant analyses.

Experimental results have shown that in the area under study Scots pine is differentiated into six populations differing in the morphological characters of cones and seeds (Fig. 35). Pine populations are clustered into two groups: East Karelian and West Karelian. The genetic similarity of the populations analysed ($D^2 = 0.01–1.78$) is noteworthy. At the same time, the pine populations and groups of populations extend from north to south. Considering that Karelia stretches over a long distance from north to south and that its nature and climate show an north-south gradient, this distribution pattern of pine is hard to explain.

It is not easy to determine the population structure of Scots pine because Karelian pine forests were cleared on a large scale in the past and the native structure of many forests have been substantially affected.

Clearly, slightly affected populations must be studied in more detail to provide a model for a close inquiry into the intraspecific variation and population structure of Scots pine.

The genetic diversity of Scots pine in Karelia was assessed using isoenzymatic analysis (Yanbaev et al., 1998). The authors studied five enzyme systems and revealed 36 allelic variants of 10 loci. The stands selected differed mainly in terms of the number of rare alleles. Analytical results showed that allele frequencies do not vary clinally from north to south and that genetic variation generally exhibits a mosaic pattern. Assessment of genetic diversity at the intrapopulation level led the authors to conclude that heterozygosity decreases from north to south due to a rising heterozygote deficit.

Analysis of the extent of subdivision and differentiation showed that about 97% of the genetic variation of Scots pine occurs at the intrapopulation level. The authors calculated Nei's genetic distance, DN (Nei, 1972) in order to quantitatively assess the genetic differentiation of Scots pine in the region. Calculations showed that the stands are similar (DN = 0.003–0.028) and that the DN value does not strictly agree with the geographic distance between stands. The authors found the northernmost Scots pine stands to be genetically isolated but the results of their electrophoretic analysis of isoenzymes led them to agree with V. L. Semerikov et al. (1993), who argued that there was insufficient evidence to justify the classification of a subspecies of Scots pine, *Pinus sylvestris ssp. lapponica* occurring north of 62° N (Pravdin, 1964). To sum up, the results of the morphological and isoenzymatic analyses of the intraspecific variation and differentiation of Scots pine in Karelia are not contradictory.

Norway spruce (including *Picea obovata* Ledeb., *P. abies* (L.) Karst. and the Finnish or hybrid spruce *P.* x *fennica* (Rgl.) Kom). Spruce forests are most common in the taiga zone of European Russia whereas in Karelia they are less prolific than pine stands and cover only 25.5% of the total forested area.

Thus, Karelian spruce forests display a highly irregular distribution pattern. They are concentrated in southern and southeastern Karelia, where argillaceous, loamy and loamy sand soils prevail. The dominance of spruce forests is also favoured by the milder climate in southern areas (Vilikainen, 1953). In northern Karelia most spruce stands are concentrated in branches of the Maanselka Range and in the Karjalanranta region where they mix with pine and birch to form thin north-taiga lichen-lithic and lichen-green moss forests.

Karelia is part of a large introgressive hybridisation zone of *P. abies* and *P. obovata*. The hybrid or Finnish spruce *P.* x *fennica* dominates here. In northern and northeastern Karelia it is mixed with trees showing some characters of Siberian spruce while in southern and southwestern Karelia it is mixed with Norway spruce. This, together with the important environment-forming role of spruce coupled with its commercial value (it is a major source of timber), maintains the interest of scientists in the species.

V. I. Bakshaeva (1959, 1962, 1963, and 1966) and M. A. Shcherbakova (1973, 1975) have studied the intraspecific variation of spruce in Karelia. Forms of spruce were distinguished on the basis of the type of branching, bark structure and the colour and shape of cones. The commercial and selection value of various forms and varieties was estimated. The endogenic, individual and ecological-geographic forms of the intraspecific characters of the generative organs of spruce were studied. Special attention was paid to the shape of the seed scales, a major diagnostic character used to distinguish between Norway spruce, Siberian spruce and hybrid spruce. M. A. Shcherbakova (1973) used the form structure of spruce stands, based on identification of forms differing in this character, in order to determine the population structure of spruce in the region. The author distinguished three groups of populations: 1) those occurring in northeastern Karelia, 2) those restricted to the Karjalanranta region and 3) those known in southern Karelia. They differ in the percentages of forms distinguished by seed scale structure, size of cones and seeds, and the average number of scales in a cone.

In the early 1990s the development of new methods in forest genetics such as isoenzymatic analysis and multivariate statistical models etc. provided an impetus for studies on the intraspecific variation of spruce in Karelia. As in the case of Scots pine attention was focused on variations in the characters of the generative sphere. In order to study the intraspecific phenotypic diversity of spruce, samples were collected at twenty localities in Karelia, in the adjacent Arkhangelsk, Vologda and Leningrad regions (Fig. 36) and in all the seed-forest areas located in the spruce zone of interest.

Analytical results for the various forms of intraspecific variation in Finnish spruce are shown in Table 13. As with Scots pine, the quantitative morphological characters of cones and seeds display higher individual levels of

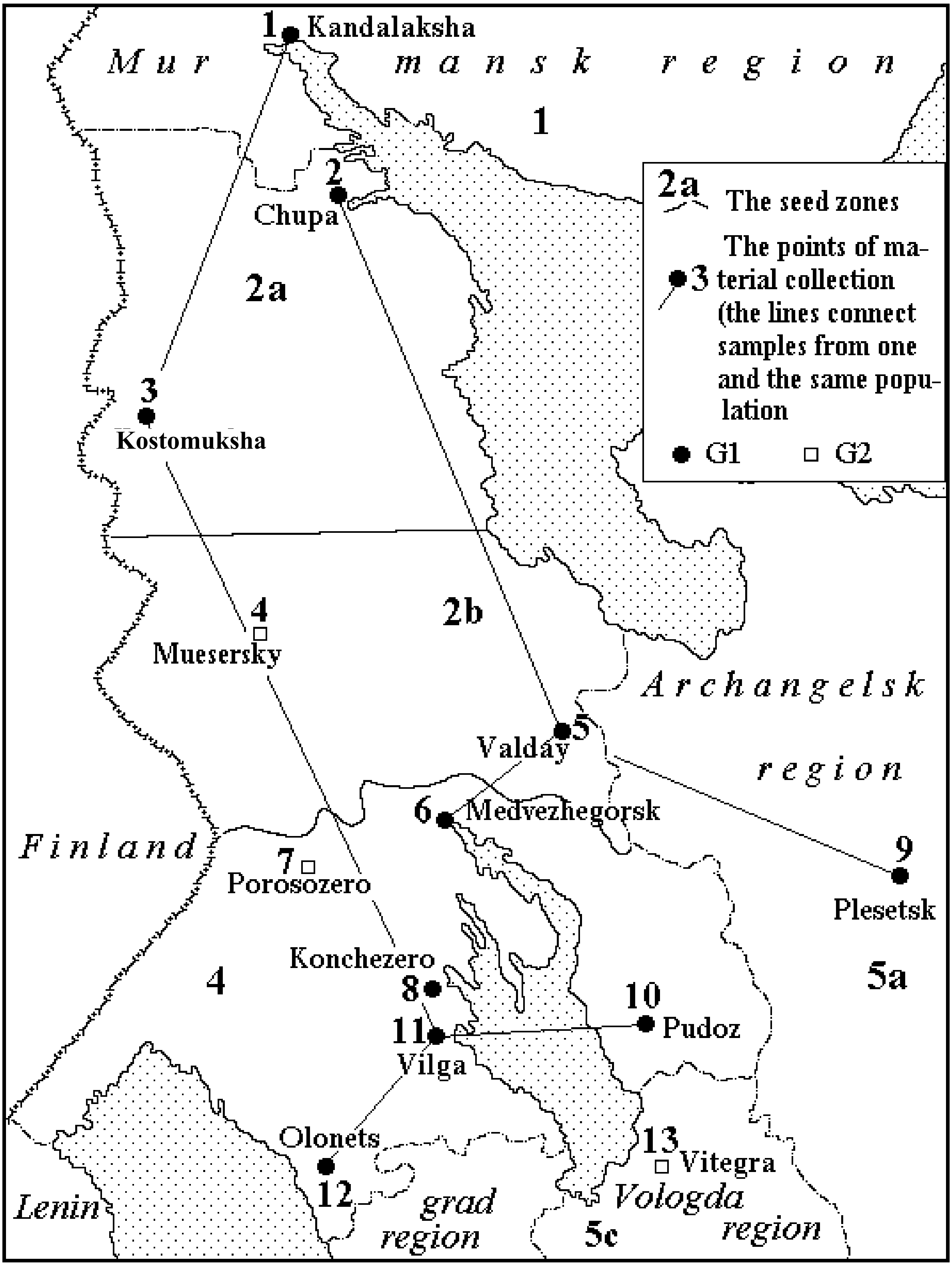

Figure 35. Scheme showing the distribution of Scots pine populations and groups of populations in Karelia and in the Arkhangelsk, Vologda and Murmansk regions

Symbols: Gl – East Karelian group (1, 3, 10, 11, 12 – Central Karelian population; 2, 5, 6 and 9 – Karjalanranta population; 8 – Kenttijärvi population); G2 – West Karelian group (4 – Muezersky population; 7 – Porajärvi population; 13 – Vytegra population); seed zones: 1 – Kuolan; 2 – Karelian (subzones: 2a – North Karelian, 2b – Central Karelian); 4 – South Karelian; 5 – Verkhnaya Dvina (subzones: 5a – South Arkhangelsk, 5b – North Vologda)

Table 13

Intraspecific variation of cone and seed parameters of Finnish spruce

Characters	Forms of variation (CV cp, %)			Recurrence coefficient (R cp)
	Endogenic	Individual	Geographic	
Cone length	11,14±0,41	13,30±0,22	9,98±1,58	0,613±0,014
Cone diameter	6,71±0,25	9,64±0,16	5,97±0,95	0,530±0,014
Cone shape coefficient	7,48±0,27	11,30±0,19	6,54±1,03	0,596±0,015
Cone mass	23,93±0,88	28,19±0,47	23,18±3,67	0,601±0,014
Mass of 1000 seeds	–	23,91±0,40	14,14±2,24	–
Length of winged seed	6,81±0,25	12,16±0,20	7,71±1,22	0,683±0,013
Scale width	5,37±0,20	9,86±0,17	5,29±0,84	0, 573±0,015
Scale length	6,89±0,25	15,33±0,26	9,75±1,54	0,558±0,015
Scale shape coefficient	6,16±0,23	15,67±0,26	6,99±1,11	0,564±0,015
Upper scale edge elongation coefficient	6,79±0,25	23,12±0,39	11,19±1,77	0,677±0,013
Number of cotyledons	–	11,58±0,20	4,48±0,71	–

diversity (CV = 9.64–28.19%) than the corresponding endogenic (CV = 5.37-23.93%) or ecological-geographic (CV = 5.29-23.18%) levels. They also displayed high heritability indices in a broad sense (R = 0.53–0.68) and low to medium intercorrelation in populations, suggesting that these characters are inherited. Comparison of the intraspecific variation pattern of Finnish spruce with that of Scots pine shows that it is character-specific. The variation pattern of Finnish spruce with regard to the ecological-geographic aspect indicates, on the one hand, that *P.* x *fennica* is phenotypically and genetically heterogeneous and, on the other, that it is poorly differentiated in the region.

Analysis of the population structure of Finnish spruce using multivariate statistical models led to the identification in the study area of twelve populations differing in the quantitative morphological characters of cones and seeds (Fig. 36). The spruce populations fell into six groups with respect to average character values and growth conditions. It should be noted that the interpopulation differentiation of Finnish spruce clearly correlates with the agroclimatic demarcation of Karelia. This correlation is especially noticeable for groups of populations. Consequently, the interpopulation differentiation of spruce, unlike that of Scots pine, shows a high degree of correlation with the north-south gradient of nature and climate variations.

In order to assess the systematic status of Finnish spruce the structure of its populations needs to be analysed on the basis of the differences in the types of seed scales between trees. Our analysis shows that the percentage of European forms in the stands increases from north to south while that of hybrid forms decreases. Siberian spruce is very scarce (8.2%) even in the northernmost Kestenga population. According to our results the systematic position of spruce in Karelia is characterised as that of a hybrid spruce similar to Norway spruce.

The genetic diversity, extent of subdivision and differentiation of Finnish spruce in Karelia was studied using isoenzymatic analysis (Potenko, Ilyinov and Goncharenko, 1993). Cone seeds were sampled in order to assess the phenotypic diversity of spruce. Electrophoretic analysis of isoenzymes showed that 15 gene-enzymatic systems in hybrid spruce are coded by 25 loci involving 70 allelic variants. The gene pools of seven populations of *P.* x *fennica* (see Fig. 36) were described in terms of allele frequencies.

Comparative analysis showed populations of *P.* x *fennica* to be genetically more similar to those of *P. abies* than to those of *P. obovata*. This evidence is in good agreement with available analytical data on the variation of Finnish spruce based on the morphological characters of its generative organs. The intrapopulation genetic diversity indices estimated as part of the study of allozymic variation were found to be slightly lower for hybrid spruce than for Norway spruce or Siberian spruce but fairly high for the *Picea* genus in general and, indeed, in comparison with other conifers in general.

Analysis of the extent of subdivision of hybrid spruce in Karelia showed that the intrapopulation constituent accounts for over 97% of total allozymic variation. Native Finnish spruce populations were found to be genetically poorly differentiated (DN = 0.010). This supports evidence for the intraspecific diversity and differentiation of hybrid spruce based on the quantitative characters of its generative organs.

The structural pattern of the Finnish spruce populations in the study area suggests that their formation is affected by several evolutionary factors. The main factors are: 1) the postglacial invasion of Siberian and Norway spruce from different refugia; 2) the introgressive hybridization of the above species; 3) natural selection which helped populations of species adapt to deglaciated land surfaces and 4) gene migration which diminished interpopulation differentiation.

Ways of conserving and improving the gene pools of Scots pine and Finnish spruce. The threat of the gene pool reduction and impoverishment of major forest-forming species implies that steps should be taken to maintain their genetic potential. Hence, our urgent goal is to delineate and protect the valuable gene pool so that these tree species are able to evolve and retain their commercial and environmental value.

Forest gene resources are usually conserved in two ways: *in situ* (naturally) and *ex situ* (artificially). The conservation of a gene pool *ex situ* (botanical gardens, experimental cultures, seed plantations, clonal archives, tissue cultures etc.) involves certain problems such as the permanent maintenance of experimental plots and unfavourable genetic changes in experimental material, etc.

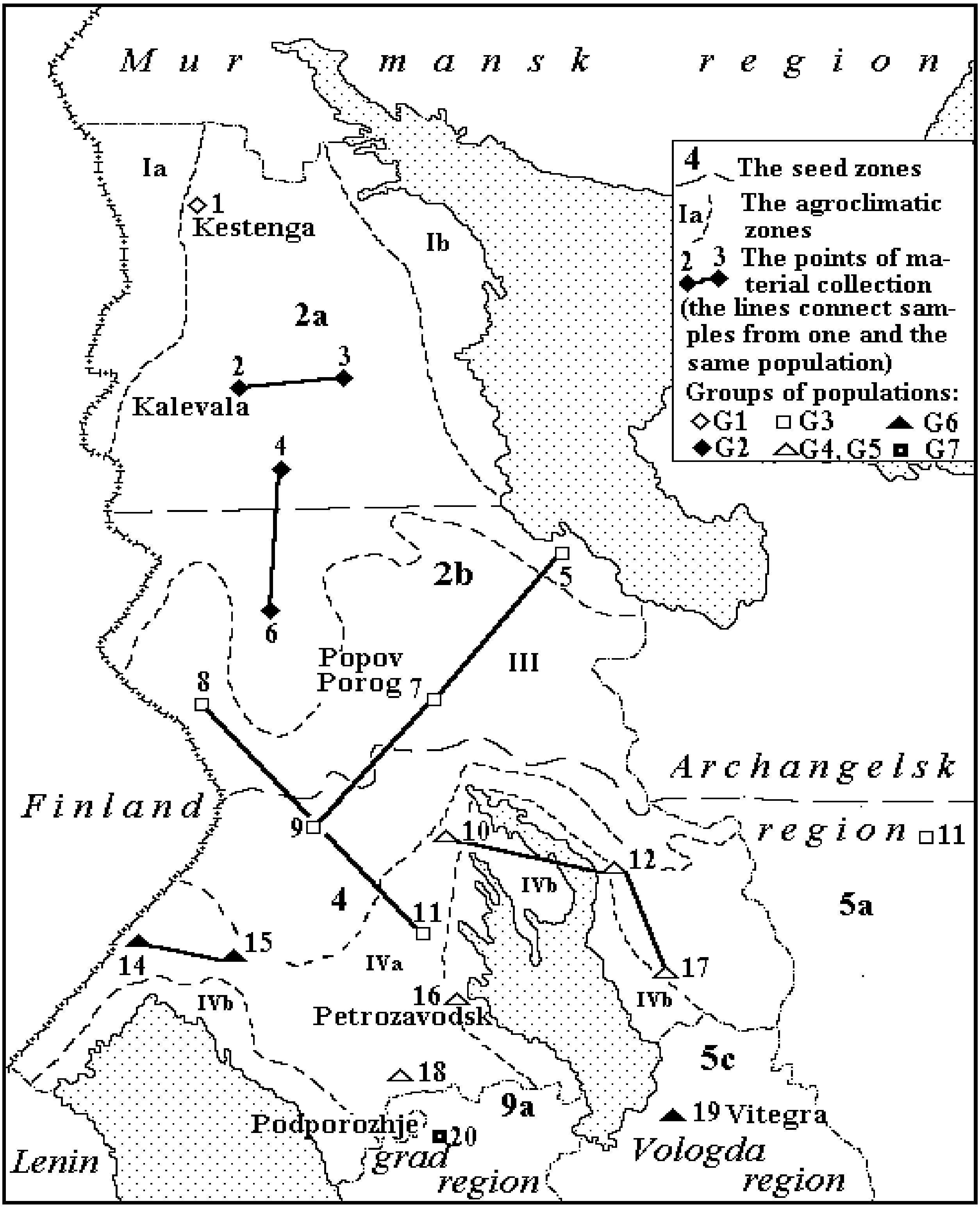

Figure 36. Scheme showing the distribution of *P.* x *fennica* populations and groups of populations in Karelia and in the Arkhangelsk, Vologda and Leningrad regions

Symbols: Gl – Kestenga group (1 – *Kestenga population); G2 – North Karelian group (2, 3 – *Uhtua population; 4, 6 – Muezerskiy population); G3 – Central Karelian group (5, 7, 9 – central Karelian population; 11 – *Plesetsk population; 8, 13 – *Lentiera population); G4 – Prionezhye group (10, 12, 17 – *Zaonezhye population; 16 – Petrozavodsk population; 18 – Verkhnie Vazhiny population); G5 – South-West Karelian group (14, 15 – *Loimola population; 19 – *Vytegra population); G5 – Podporozhye group (20 – Podporozhye population); * – isoenzymatic analysis was performed; agroclimatic zones: I – Maanselka-Karjalanranta province (Ia – Maanselka, Ib – Karelian Coast); II – Northern Lake zones; III – Central zones; IV – Southern zones (IVa – Southern Lake zones, IVb – Priozerny zones); for the symbols of seed zones, see Figure 35

In most cases these problems may be fully or partially resolved through the conservation of species in their native environments in national parks, strict nature reserves, botanical and forest reserves and valuable undisturbed zones. Unfortunately, some protected areas fail to fully represent the gene pool. Moreover, the restrictions imposed on human activities in strict reserves, nature reserves and national parks contradict the steps required for maintaining the gene pool. The best type of protected areas, i.e. that which meets all conservation and regeneration requirements, is the genetic reserve. This differs from other types in terms of the location, size and nature of routine activities that reflect the population structure and other characteristics of protected species.

Genetic reserves were first selected in Karelia in 1988 by the Laboratory of Cytology, Genetics and Selection of Tree Species, Forest Research Institute, KRC, RAS. As available evidence for the genotypic and spatial population structure of major forest-forming species was clearly insufficient, genetic reserves were delineated on the basis of the prevailing seed types encountered. During 1988–1989 four genetic spruce reserves and four pine reserves covering 2.8 and 2.1 thousand hectares respectively were selected in the South Karelian seed zones. During 1990–1994 a further eight Scots pine reserves (3.35 thousand hectares) and three Norway spruce reserves (1.26 thousand hectares) were proposed in the Karelian and South Karelian seed zones.

Intense long-term deforestation has substantially reduced the area of primeval forests in Karelia. Especially in the North Karelian seed subzone few stands meet all genetic reserve requirements.

One way to selectively improve forest gene resources is to produce experimental cultures. Efforts have been made in Karelia since 1975 to form permanent seed forest reserves based on genetic selection (Table 14). In the early stages, plus-trees and stands were selected (Yermakov, 1967). Seed plantations are the most valuable part of a seed reserve. They represent the vegetative and seed progeny of almost all plus-trees selected in Karelia.

Table 14

Pine and spruce seed reserves in Karelia
(based on data presented by Goscomles Karelia as of 1.01.1999)

Type of reserves	Total	Species	
		Scots pine	Finnish spruce
Plus-trees	2042.0	1407.0	491.0
Plus stands, ha	571.2	387.1	180.0
Seed plantations, ha	500.9	399.3	59.0
Seed plots, ha	10.0	–	10.0

Plus-trees for first generation plantations were selected with regard to phenotype alone. To evaluate them genetically by their progeny experimental cultures were sown over an area of about 42 hectares. The growth of the progeny of plus pine-trees was studied and the results obtained showed that 39% of semi-sib families grew faster than trees in the control group (Mordas, Rayevsky and Akimova, 1998). The selection effect varied from 5.3 to 22.1% and rose to 39.5% in one case. The average selection effect produced by first-order plantations was 6% for local populations. In controlled hybridization experiments heterosis was observed in one variant of polycrossing. The growth rate of hybrids was 66.9% of that of the control group. Experimental results confirmed the potential value of selecting and growing plus pine-trees with a view to producing hereditarily improved seeds and to preserve a valuable gene pool *ex situ*.

Selection and reforestation can be carried out intensely using local stock and seeds from other regions. Of great practical value in this connection are the results of experiments on geographic cultures. During 1977–1978 geographic cultures of Scots pine and Norway spruce were sown in Karelia under a programme for the formation of a Soviet-Union geographic culture network.

The growth and survival of the Scots pine cultures (45 provenances) planted in the South Karelian seed zone in the mid-taiga subzone (Medvezhegorsk forestry farm, Kumsa forest estate), were analysed. The latitude of seed provenance showed a close positive correlation ($r = 0.92$) with the survival of variants while height growth rates showed a negative correlation ($r = – 0.67$) with latitude. Selection should be based on local populations of Scots pine that combine optimum growth rate and resistance to unfavourable environmental factors.

The study of the growth and survival of the Norway spruce cultures planted in the South Svyatozero forest estate at the Pryazha forestry farm (South Karelian seed zone) revealed a different pattern. Norway spruce provenances from western Russia and those from the Baltic region proved to be the fastest growing and most intact. The growth rate of the variants displayed a clearly negative correlation ($r = – 0.68$) with the longitude of seed provenance. It appears that as the characters of Siberian spruce become more apparent on moving eastwards the growth rates of the provenances slows down. Karelian provenances were found to be similar to Norway spruce. This result agrees with available data on the intraspecific variation and population structure of Finnish spruce. This evidence supports E. G. Bobrov's hypothesis (Bobrov, 1978) concerning the replacement of Siberian spruce by Norway spruce at least in this part of the introgressive hybridization zone.

Conclusion. In order to assess possible changes in intraspecific diversity parameters caused by the impact of human activities on natural complexes, the genetic and phenotypic structures of untouched climax cenopopulations of Scots pine and Finnish spruce should be studied thoroughly. To study and improve the genetic potential of pine and spruce in Karelia by selection it is necessary: 1) to examine the phenotypic and genetic structures of intact Finnish spruce and Scots pine populations in the primeval coniferous forests that have survived in some parts of Karelia; 2) to thoroughly analyse the intraspecific variation of pine and spruce including hierarchic structure (the contribution of each form of variability to the total variance of characters); 3) to seed experimental population cultures in various environments with a view to studying the progenies of populations; and 4) to continue the selection of genetic reserves and to launch genetic monitoring there.

3.1.3. Understanding Karelia's floristic zones: current state and prospects

Introduction. To date a number of biogeographical zonation including geobotanic schemes (Tsinzerling, 1932; Geobotanic…,1989; Yurkovskaya, 1993) have been proposed for Karelia by various authors. Attempts to demarcate Karelia on the basis of forest type (Yakovlev & Voronova, 1959) and forest vegetation (Fedorets et al., 2000) have been made as a part of a geobotanic zonation. Grassland (Ramenskaya, 1958) and mire (Yelina et al., 1984) provinces have also been delineated and a map of the geographic landscapes of Karelia has been drawn. Using this map as a basis other zonation projects have been launched and are presently in progress (Gromtsev & Kolomytsev, 1998; Gromtsev, 2000).

In the late 19th century the Finnish botanist J. Norrlin performed a biogeographical zonation of East Fennoscandia (see, e.g. Mela & Cajander, 1906). The scheme he produced has been widely used by Scandinavian naturalists in floristic research (Red Data Book…, 1998; Retkeilykasvio, 1998; Flora Nordica, 2000 et al.). It should be noted that his biogeographic provinces are still used in Finnish botanic literature when referring to samples collected in the Russian part of East Fennoscandia.

The floristic zonation of Karelia developed more recently by Ramenskaya (1960) agreed largely with that of the Scandinavian biogeographic provinces except for the addition of two new provinces, Belomorian (White Sea) and Shoksha. Later, however, M.L. Ramenskaya (1983) accepted the Scandinavian scheme in full, removed the Belomorian province demarcation and reduced the rank of the Shoksha and Northwestern mountain (Karelian portion of the Kuusamo province) provinces to subprovinces (Sheltozero and Southwestern) in the Olonets and Imandra provinces, respectively. For sake of convenience all provinces were given Russian names. M.L. Ramenskaya also briefly characterised the provinces and described their floristic and vegetative patterns. She emphasised, however, that the provinces were large, their boundaries tentative and the zonation scheme therefore notional because «the region is too poorly understood floristically to allow the distinguishing of provinces solely or generally on the basis of floristic characteristics» (Ramenskaya, 1983: p.193).

Accepting the existing floristic zonation scheme as a working tool and considering that the floristic provinces proposed by M.L. Ramenskaya for Karelia are almost complete counterparts to the Scandinavian biogeographic provinces, we follow Scandinavian traditions in delineating and naming floristic provinces and use for the sake of convenience the following Latin names and abbreviations: ***Kl*** – *Karelia ladogensis* – Priladozhsky district; ***Kol*** – *Karelia olonetsensis* – Olonets district; ***Kb*** – *Karelia borealis* – Suojärvi district; ***Kon*** – *Karelia onegensis* – Zaonezhsky district; ***Kton*** – *Karelia transonegensis* – Vodlozero district; ***Kpoc*** – *Karelia pomorica occidentalis* – Kem district; ***Kpor*** – *Karelia pomorica orientalis* – Vygozero district; ***Ks*** – *Regio Kuusamoënsis* – Imandra district (Southwestern subprovince); ***Kk*** – *Karelia keretina* – Topozero district.

It should be noted that the term 'biogeographic province' corresponds to that of floristic district while at the level of planetary zonation a province corresponds to a high-ranking phytochorion and covers a very large area. For instance, the North European province, which together with Karelia forms part of the Boreal zone of the Holarctic, extends from Norway to the Timan Range and the Upper Kama Upland (Takhtadjan, 1978).

The Pudozh floristic district as delineated by M.L. Ramenskaya (1960, 1983) is not accepted within the Scandinavian scheme as most scientists consider it to be outside Fennoscandia. More recently it was given the name *Karelia pudogensis* and the abbreviation ***Kp*** (Kravchenko & Kuznetsov, 1995). The eastern and southern parts of *Kp* are in the neighbouring Arkhangelsk and Vologda Oblasts; it seems to be combined with the Vytegra-Andoma floristic district of the Vologda Oblast (Orlova, 1993) as part of the Sukhona floristic unit recognised by V.A. Bubyreva (1992) in the Sukhona subprovince (Kravchenko & Kuznetsov, 2001).

Methods. The comparative floristic principle is more applicable than geographic, hierarchic or florogenetic principles as well as the criterion of endemism as generalised and formulated by A. I. Tolmachev (1974) for distinguishing low-ranking phytochoria (floristic provinces and districts). Floristic zonation based on quantitative characters has been used successfully over the past few decades for comparing floristic lists as well as taxonomic and typological spectra in various nature zones (Baranova et al., 1971; Malyshev, 1973; Zolotukhin, 1987; Abramov, 1994; Naumenko, 1998 et al.). Relevant mathematical methods have been developed (Schmidt, 1980, 1984, 1987; Yurtsev & Semkin, 1980; Malyshev, 1987; Malyshev et al., 1998; Semkin, 1987 et al.).

We believe that available data concerning the distribution of vascular plants in Karelia is sufficiently complete for a comparative floristic analysis of the biogeographic provinces (floristic districts). In our work we used lists of vascular plants from the Karelian provinces (Kravchenko et al., 2000) from which we excluded spontaneous hybrids, alien plants (except archeophytes) and escapes. Thus, we only analysed aboriginal plants and archeophytes. In order to improve comparison we interpreted species in the broad sense. Thus, microspecies of the genera *Dactylorhiza, Polygonum, Ranunculus, Taraxacum* etc. were not analysed separately and species of the genera *Hieracium* and *Pilosella* were considered on a sectional level (Shlyakov, 1989 a, b).

In order to comparatively assess the floristic provinces of Karelia the most significant taxonomic (spectra of leading families, species composition) and typological (structure of geographic elements) indices of their flora were determined.

Taxonomic structure of the provinces: comparative analysis. Taxonomic structure is analysed in order to assess original floristic patterns and so provide a basis for the demarcation of floristic districts (in spite of the fact that the spectra of leading families reflect the oldest environments in which flora evolved), and also to primarily characterise phytochoria of higher rank than floristic districts, i.e. floristic provinces and higher (Malyshev, 1987.). The spectra of leading families ranked according to the number of species (Table 15) were compared. Our analysis shows that the top portions of these spectra (the first ten families) for the different provinces together include fifteen families: *Cyperaceae, Poaceae, Asteraceae, Rosaceae, Caryophyllaceae, Ranunculaceae, Scrophulariaceae, Orchidaceae, Polygonaceae, Salicaceae, Juncaceae, Brassicaceae, Ericaceae, Fabaceae* and *Apiaceae*. The first five mentioned are invariable in the 'top ten' while the first four occur in the above order in all provinces except for *Kol*, *Kp* and *Kpor* where the family *Poaceae* heads the list. Since these three provinces partly lie outside Karelia we considered them only in part although their special position at the eastern and southern boundaries is also taken into account. The same is also true for *Kton* where the first two families listed are represented by about the same number of species. V.A. Bubyreva (1992) draws the boundaries of floristic provinces to coincide with the areal distribution boundaries of key plant species.

This together with the presence of coastal species seems to explain some of the other characteristics of the spectrum of leading families in the *Kpor* province such as the absence of the families *Orchidaceae, Scrophulariaceae, Polygonaceae* from the top ten and the relatively high rank of the families *Ericaceae* and *Apiaceae*. It should be noted that the family *Orchidaceae* is also absent from the list of leading northern species (Ramenskaya, 1983) and that the spectrum is headed by the family *Poaceae*.

The family *Ranunculaceae* occupies fifth or sixth position in the spectra of all provinces with the exception of *Kb* where it drops to eleventh position. The family *Brassicaceae* is in the top ten only in *Kon* and *Kl* (tenth in the list) and in eleventh position in *Kol*. The family *Juncaceae* lies in the top part of the family spectrum in all the provinces of the north-taiga subzone (eleventh position in Ks) and in *Kb*. According to A. I. Tolmachev (1974) *Juncaceae* is characteristic of the Arctic floristic province since the genera *Juncus* and *Luzula* are dominated by tundra and arctalpine species. The family *Salicaceae* ranks highly in all provinces except for *Kl*, *Kon* and *Kk* where it occupies between eleventh and thirteenth positions in the list.

In the north-taiga subzone the more thermophilic families *Apiaceae* and *Fabaceae* lie in the top ten in only two provinces. The family *Apiaceae* is in the top portion of the spectrum only in *Kpor* presumably because this province is otherwise floristically poor. Thus, the number of species in the family *Apiaceae* (12) in *Kpor* is the same as in the neighbouring provinces of *Kton*, *Kpoc* and *Kon*. The family *Fabaceae* holds tenth position in the family spectrum of *Kk*, the northernmost province (chiefly by virtue of the high number of species of the genera *Astragalus* and *Lathyrus*) while in all other provinces it ranks between eleventh and thirteenth.

This group of leading families is generally typical of the Boreal floristic province (Tolmachev, 1974). With the exception of *Polygonaceae*, *Apiaceae* and *Ericaceae* the same families top the family spectra in the Karelian-Murmansk region, in Finland, in the Northern territory and in the Leningrad Oblast (Ramenskaya, 1983). The proportion of species belonging to the ten leading families in each floristic province varies from 53% to 57% and increases towards the north. This feature is also typical of boreal flora in general (Tolmachev, 1974).

Comparison of family species spectra using the $\chi 2$ method (Plokhinsky, 1970) has shown that differences between many pairs of provinces are not significant (Table 15). According to this method only the *Kpor* province possesses a unique spectrum.

Comparison of the spectra of leading families using Gamm's rank correlation coefficient[1] shows that most provinces are associated on a fairly high level (coefficient values 0.92–0.96). *Kpoc* shows a high correlation coefficient with *Kk* (0.96) and also with *Kol*, *Kon* and *Kl* (0.95 each). Links to the main massif are much weaker in *Kpor* (0.79), *Ks* and *Kb* (0.86 each). The family spectra of the *Kpor* and *Kb* provinces have already been discussed earlier in the chapter. As regards the province *Ks*, the main characteristics of the spectra of its leading families are the high positions of the families *Orchidaceae* (fifth) and *Salicaceae* (seventh) as well as the presence of the family *Ericaceae* in the top portion of the spectra (tenth position) and the absence of the family *Polygonaceae* (fourteenth position). It has been noted earlier that all these provinces are partly outside Karelia. This applies equally to Kol, Kton and Kp, but their rank correlation coefficient is less markedly affected.

Comparison of the species composition of flora is important when low-ranking phytochoria such as floristic districts and provinces are to be distinguished (Malyshev, 1973; Schmidt, 1980). The results of our comparison of floristic lists are shown dendrogrammatically in Fig. 37.

Clustering by the complete linkage method and graphic representation[2] clearly show the isolation of provinces in the north and mid-taiga subzones. The mid-taiga provinces are interconnected more closely than north-taiga provinces. The closest degrees of correspondence are observed between *Kon*, *Kol* and *Kl*.

Geographic structure of the provinces: comparative analysis. To analyse and compare the geographic structure of provincial flora species were grouped according to area (including longitudinal and latitudinal characteristics)

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[1] Gamm's method is employed in the computer program STATISTICA 4.5 for Windows and is recommended for use with bound ranks.

[2] Used in the computer program STATISTICA 4.5 for Windows.

Table 15

Taxonomic (family-species) spectra of flora in the biogeographic provinces of Karelia

Family	Kl		Kol		Kp		Kb		Kon		Kton		Kpoc		Kpor		Ks		Kk	
	Number of species	Position of family	Number of species	Position of family	Number of species	Position of family	Number - of species	Position of family	Number - of species	Position of family	Number - of species	Position of family	Number - of species	Position of family	Number - of species	Position of family	Number of species	Position of family	Number of species	Position of family
Cyperaceae	68	1	59	2	43	2	48	1	69	1	50	1	71	1	50	2	62	1	65	1
Poaceae	60	2	62	1	48	1	43	2	60	2	49	2	63	2	52	1	46	2	64	2
Asteraceae	42	3	43	3	38	3	33	3	44	3	41	3	35	3	26	3	30	3	36	3
Rosaceae	37	4	32	4	27	4	25	4	35	4	30	4	34	4	22	4	27	4	32	4
Caryophyllaceae	31	5	24	7	20	6	15	6-7	27	7-8	22	6	26	5	20	5	19	6	25	5
Ranunculaceae	30	6	29	5	22	5	10	11-12	29	5-6	28	5	20	7	17	6	14	9	18	6
Scrophulariaceae	28	7	26	6	18	7	17	5	29	5-6	19	8	19	8	10	11	15	8	17	7-9
Orchidaceae	22	8-9	21	8	16	8	15	6-7	27	7-8	20	7	21	6	6	17-18	20	5	17	7-9
Polygonaceae	22	8-9	20	9	15	9-10	11	9-10	19	9	15	9	16	10-11	9	12-13	8	14-16	15	10-11
Brassicaceae	17	10	15	11-12	8	17	7	16-17	17	10	13	11	15	12-13	7	15-16	10	12-13	11	15
Fabaceae	16	11	15	11-12	12	11	8	14-15	15	12	12	12-13	15	12-13	9	12-13	10	12-13	15	10-11
Juncaceae	14	12-13	12	13	9	15-16	12	8	12	15-17	10	14-15	17	9	12	7-8	12	11	17	7-9
Salicaceae	14	12-13	18	10	15	9-10	11	9-10	16	11	14	10	16	10-11	11	9-10	18	7	14	12
Apiaceae	11	16	11	14-16	10	12-14	8	14-15	12	15-17	12	12-13	12	14-15	12	7-8	5	19-20	12	14
Ericaceae	10	17-18	10	17-18	10	12-14	10	11-12	10	18	10	14-15	12	14-15	11	9-10	13	10	13	13
Total number of species analysed	674		623		487		427		674		529		597		422		475		563	
In 10 leading families (number/%)	357	52.9	334	53.6	262	53.7	230	53.8	356	52.8	288	54.4	338	56.6	233	55.2	264	55.6	321	57.0
Degree of similarity of provinces	a*		a b		c		c d		a		a c		b c		e		d		b c d	

* The same letters are used to indicate provinces which do not differ from each other according to the χ^2 method; positions of families listed in the top ten are shaded.

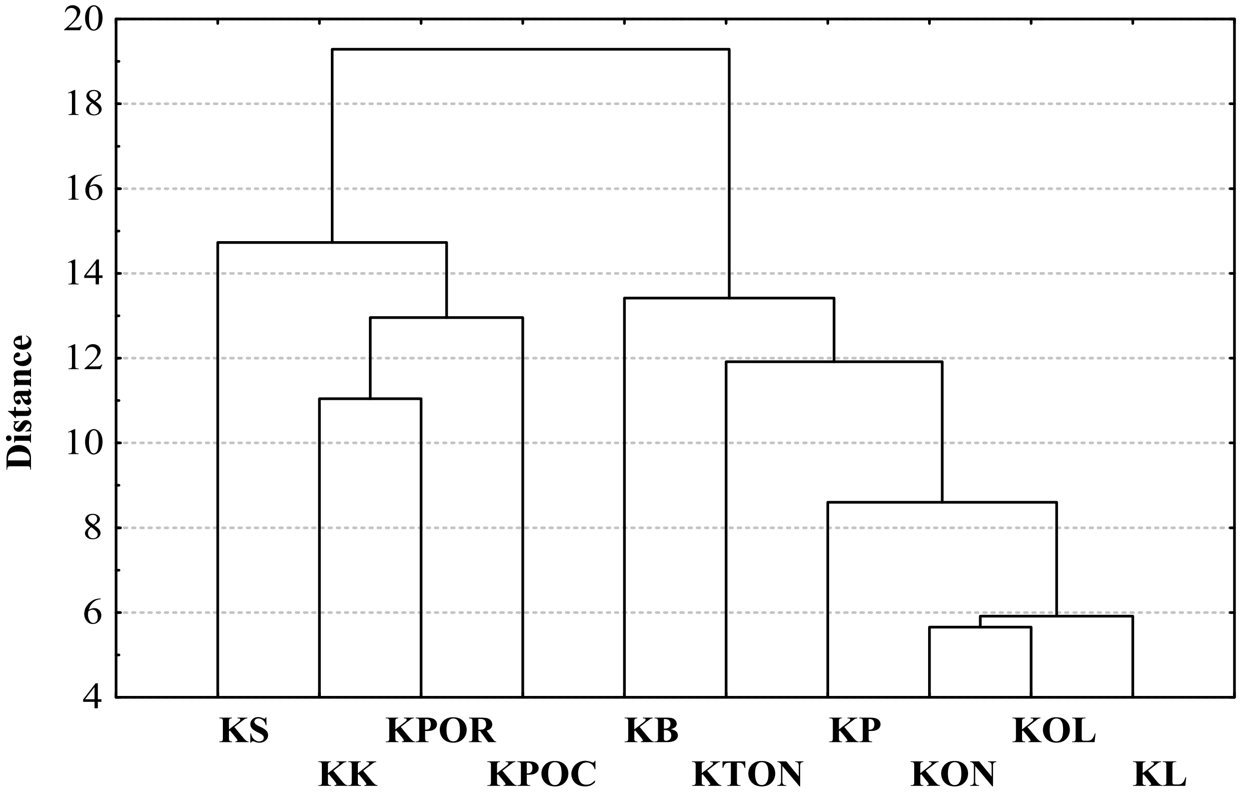


Fig. 37. Dendrogram showing the similarity of provincial floras in species composition (with regard to the occurrence of species): Euclidean metrics, complete linkage method

using the biogeographic coordinate system (Yurtsev, 1968). Altogether 28 types of distribution areas (geographic elements; Table 16) were distinguished.

The significance of differences between geographic structures was corroborated by the χ^2 method only for the *Ks* and *Kpor* provinces (Table 16).

Table 16

Geographic structure of flora in the provinces of Karelia (number of species)

Geographic element	Biogeographic provinces (floristic districts)									
	Kl	Kol	Kp	Kb	Kon	Kton	Kpoc	Kpor	Ks	Kk
A-amph	0	0	0	0	0	0	0	0	1	0
A-Eur	1	1	0	0	1	0	6	5	1	5
A-Euras	2	1	0	0	2	1	3	2	6	2
A-circ	5	6	1	1	7	2	14	8	7	16
AA-amph	4	1	1	1	2	1	3	2	6	5
AA-Eur	2	1	0	1	1	1	3	0	5	2
AA-Euras	2	2	0	2	3	2	7	2	7	6
AA-circ	6	7	1	2	8	5	15	6	24	21
AB-amph	3	2	1	2	4	2	6	4	4	6
AB-Eur	8	3	3	3	8	4	15	10	9	23
AB-Euras	9	11	9	8	12	10	17	11	18	18
AB-circ	28	24	19	19	31	21	39	29	40	42
End	0	0	0	1	0	1	5	2	4	5
Northern fraction	70	59	35	40	79	50	133	81	132	151
B-amph	9	7	7	7	8	6	8	6	5	8
B-Eur	45	38	27	28	43	29	33	20	23	28
B-Euras	184	186	163	145	196	179	162	125	137	146
B-circ	130	133	106	101	134	116	117	96	101	112
Boreal fraction	368	364	303	281	381	330	320	247	266	294
BN-amph	3	3	2	3	3	2	3	2	1	2
BN-Eur	18	7	6	4	11	7	5	2	2	2
BN-Euras	39	33	27	21	37	22	20	14	13	17
BN-circ	7	7	7	5	9	6	5	6	4	5
N-Eur	19	13	8	3	11	9	0	1	1	1
N-Euras	27	24	20	5	21	20	7	1	5	8
N-circ	1	1	0	0	1	1	1	1	0	0
Southern fraction	114	88	70	41	93	67	41	27	26	35
P-amph	1	1	0	0	0	0	0	0	0	0
P-Eur	14	8	5	5	8	6	8	6	2	6
P-Euras	54	51	37	30	53	38	39	26	19	26
P-circ	47	47	34	27	48	34	42	35	26	41
Plurizonal fraction	116	107	76	62	109	78	89	67	47	73
Similarity	a*	b	c	d	a b	b c d	e	f	g	e

* The same letters are used for provinces that do not differ according the χ^2 method.

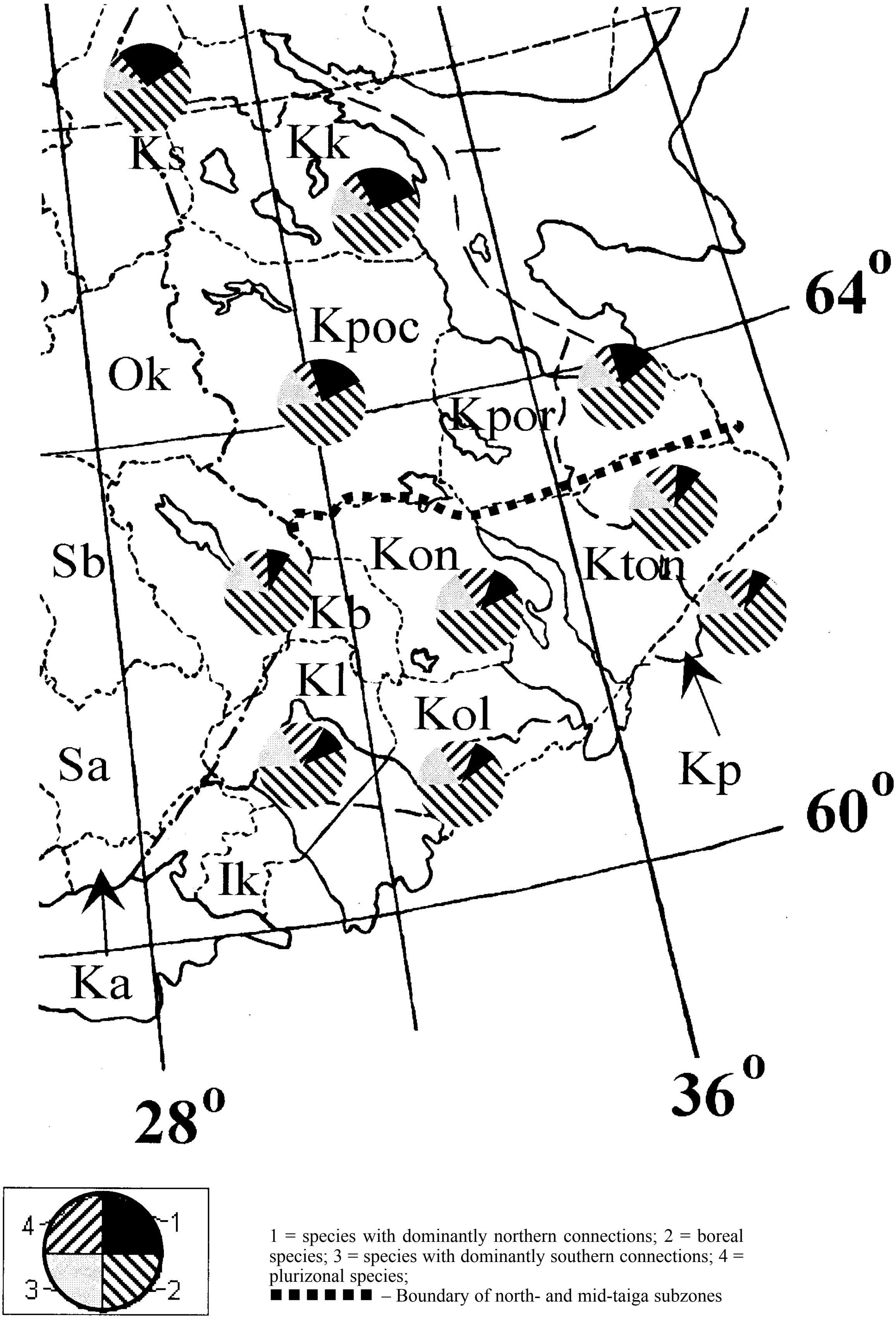
N.B. Geographic elements are composed of latitudinal and longitudinal geographic coordinates separated by a dash. Latitudinal characteristics: A = Arctic, AA = Arctalpine, AB = Arctoboreal, B = boreal, BN = boreonemoral, N = nemoral, P = plurizonal; Longitudinal characteristics: amph = amphi-Atlantic, Eur = European, Euras = Eurasian, circ = circumpolar. End = endemics in East Fennoscandia.

The combination of correlations of latitudinal geographic elements into northern, southern, boreal and plurizonal fractions are shown diagrammatically on a sketch map (Fig. 38). North-south variations in correlations are most noticeable for fractions of southern and northern elements and less apparent for the boreal fraction. The proportion of plurizonal elements is relatively stable.

The dendrite of correspondence between the geographic structures of the provinces according to the single linkage method employing Gamm's rank correlation coefficient (Fig. 39) displays the same relations between the provinces as the dendrogram (comparison of species composition). Two clusters that combine mid and north-taiga provinces are distinguished; as the degree of correlation increases *K*s and *Kpor* are the first to be distinguished. The provinces of the mid-taiga subzone correspond far more closely with the geographic structures of *Kon* and *Kton* being practically identical (0.99).

Comparative analysis of the species composition and geographic structure of provincial flora has clarified some important points.

Firstly, the existence of a distinct floristic boundary overlapping the geobotanic boundary between the mid and north-taiga subzones was collaborated.



1 = species with dominantly northern connections; 2 = boreal species; 3 = species with dominantly southern connections; 4 = plurizonal species;
■ ■ ■ ■ ■ ■ – Boundary of north- and mid-taiga subzones

Fig. 38. Ratio of the latitudinal fractions of geographic elements in provincial floras

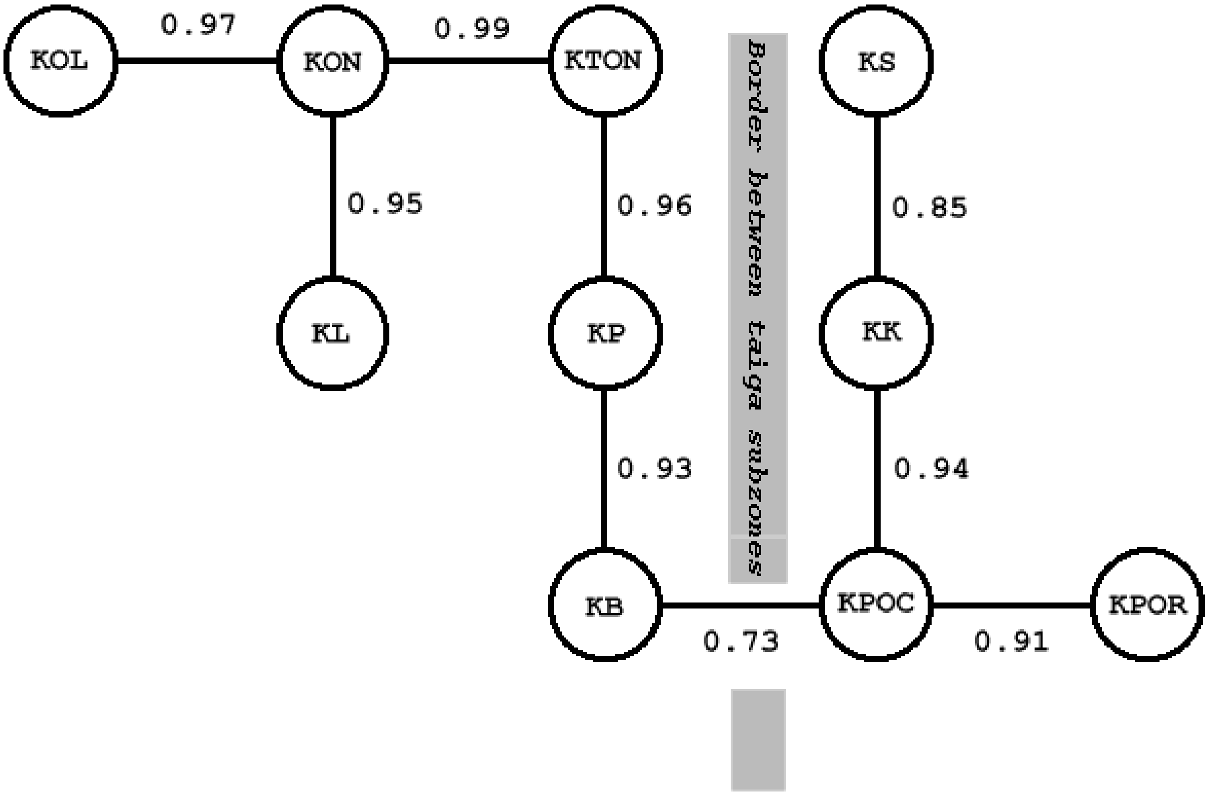


Fig. 39. Dendrite showing degree of correspondence between the geographic structures of provincial flora

Secondly, differences between three southern provinces, *Kl*, *Kol* and *Kon* proved to be very small. As each province has a native pattern of its own it is desirable to redraw the boundaries between them. For example, the *Kl-Kol* boundary should be corrected as it was previously drawn along the administrative border in place at that time between the Olonets province and the Great Principality of Finland rather than along natural boundaries. Furthermore, the native pattern of the eastern part of *Kol* province shows a much greater correspondence to *Kon*, thus allowing it to be distinguished either as an independent floristic province (Ramenskaya, 1960) or as a subprovince of *Kol* (Ramenskaya, 1983). At the same time, the correspondence between the geographically separated provinces *Kl* and *Kon* is not surprising as they have much in common, e.g. their locations on the shores of Europe's two largest lakes, the extensive occurrence of compositionally diverse bedrock exposures bearing a variety of relict species from both the climatic pessimum and the Holocene optimum, and the history of human colonisation (i.e. the composition of archeophytes).

Thirdly, no differences in the systematic and geographic structures of *Kk* and *Kpoc*, two of the largest provinces in the north-taiga subzone of Karelia, have been found. This does not imply that this vast territory which covers almost a half of Karelia is floristically homogeneous. On the contrary, each of these provinces incorporates at least two heterogeneous floristic units that can be distinguished as independent provinces.

Obviously, the western portion of *Kpoc* which lies in the branches of the Maanselka Range – West Karelian Upland may be distinguished within the *Kpoc* province, as too may be the eastern (Pribelomorian) section.

Conclusion. Zonation is usually the final goal of a floristic study. Before demarcating a territory it should be thoroughly studied floristically. It would be misleading to claim that the flora of Karelia has been exhaustively described and assessed. Many areas, especially those in northern, northeastern, eastern and central Karelia, are still poorly studied. However, a large-scale field study has been carried out actively over the past decade and we are hopeful that a comprehensive floristic zonation will be attempted in the near future. As detailed floristic evidence is already available for some localities (local flora complexes) comparative floristic methods may be employed together with mathematical tools to study the spatial differentiation of Karelian flora.

Experience in the comparative study of local flora in West and Middle Karelia (Gnatiuk et al., 1999; Gnatiuk & Kryshen, 2001) has shown this line of research to be promising.

It is essential that the distribution of differential and other species be analysed and that the boundaries of their distribution areas be compared and the zones in which they concentrate identified. This is the essence of the chorological principle of floristic zonation (Bubyreva, 1993). According to V.A. Bubyreva (1993) the comparative-floristic principle is used to describe and delineate provinces. L.A. Takhtadjan (1978) believed that maps showing the distribution areas of all species provide a perfect basis for zonation. Only preliminary steps have been taken in this field in

Karelia, i.e. spot maps have been drawn showing the distribution of certain rare and protected species (Kravchenko & Kuznetsov, 1995; Kravchenko et al., 2000) and those of 576 vascular plant species for Middle Karelia (Gnatiuk, 1999).

During the final phase of zonation the new scheme should be compared with the existing zonation of adjacent regions while local districts should be included into a general regional scheme of phytochoria.

3.2. Mosses in protected areas

Introduction. Karelia has a highly diverse bryoflora and is situated in Fennoscandia which has altogether some 900 moss species. This large number of mosses is a result of the wide variety of biotopes present, especially of the rupicolous type. Pioneer studies of Karelian mosses were conducted in the mid-19th century by Russian naturalists who reported 76 species (Experience …, 1838 et al.). Finnish and Swedish scientists were also active in the study of Karelian bryoflora. The results of their work were summarised by J. Bomansson & V. Brotherus (1894), V. Brotherus (1923) and C. Jensen (1939). A paper by J. Bomansson and V. Brotherus (1894) summarising the results of late 19th century bryological research lists 326 moss species for Karelia.

The work by V. Brotherus (1923) and C. Jensen (1939) was followed by the study of bryoflora, mainly in western Karelia, by various Finnish botanists (Kotilainen, 1929, 1944; Tuomikoski, 1935 a, b, 1939, 1940; Auer, 1942; Huuskonen, 1953; Halonen & Ulvinen, 1996 et al.). Finnish bryologists revised various herbaria and so helped towards a better understanding of Karelian bryoflora (Koponen, 1967, 1968; Ulvinen, 1969; Hinneri, 1976; Wahlberg, 1998 et al.).

The early 20th century saw a growing interest in geobotanical research and this led to new collections of the bryological material being stored in the Herbarium of the V. L. Komarov Botanical Institute, RAS (LE). In all, a great deal of attention has been paid by mire scientists (Yurkovskaya, 1967; Maksimov, 1988 et al.) to the moss cover of Karelia. The moss species composition of grassland phytocenoses and moss cover-grass cover relationships were discussed by V.A. Zaikova (1958, 1966). During 1968–1981 Karelian mosses were studied by L.A. Volkova (Volkova, 1972, 1977, 1978, 1979, 1981a et al.) who summarised her results and other available data in “Hand book of mosses of Karelia” published as late as 1998 (Abramov & Volkova, 1998). Listed in this valuable guide are both species already known in the region and those mosses that are likely to be found. However, the occurrence and distribution of species are not covered by the authors.

Further impetus for the bryofloristic study of the region was provided by L.A. Volkova and A.I. Maksimov (1993) who summarised all available data on Karelian mosses, drew up a systematic list of 415 (moss species and described the distribution of these species over the 12 floristic provinces distinguished by M. L. Ramenskaya (1960; see Fig. 40). The list is a useful guide in comparative floristic studies.

Data on rare Karelian bryophytes are summed up in the Red Data Book of Karelia (1995) (hereinafter referred to as RDBK) and in the Red Data Book of East Fennoscandia (1998) (RDBEF). An annotated list of rare mosses was published by A.I. Maksimov (2000).

We have been studying moss flora since 1997 in a number of areas to be protected as part of the so-called Green Belt of Fennoscandia as well as elsewhere in Karelia. Based on the results of this and earlier studies, lists of mosses have been published for most of the protected areas in Karelia, i.e. the Kivach Strict Reserve (Maksimov et al., 1995), the Kostomuksha Strict Reserve (Boichuk, 2001), Paanajärvi National Park (Maksimov, 1995), the proposed Kalevala (Boichuk, 1998), Ladoga Skerries (Maksimov & Maksimova, 2000), Koitajoki (Maksimov et al., 1998 a) and Tuulos national parks (Maksimov et al., 1998 b), various mires in the Koivu-Lambasuo Reserve (Maksimov et al., 1997), as well as the Tolvajärvi (Maksimov et al., 1998 a, b), Keret and Shuiostrovsky reserves (Maksimov & Maksimova, 1999). Until the present the above areas, with the exception of the Kivach Strict Reserve, the Ladoga Skerries Park and the Paanajärvi Park, had not been the subject of significant bryofloristic study. Some data on the mire bryoflora of the proposed Tuulos and Koitajoki national parks is available in various geobotanical publications (Kuznetsov & Maksimov, 1995; Shevelin & Tokarev, 1995). All the moss flora studied in protected areas may be considered to be local bryoflora complexes. A collection of about 4000 bryophyte samples is kept in the Herbarium of the Institute of Biology, Karelian Research Centre, RAS.

The goal of our project has been to summarise all available data on existing and proposed protected areas in Karelia, to reassess data on the species composition of mosses in floristic provinces first presented by L.A.Volkova and A.I. Maksimov (1993), and to extend the list of Karelian mosses. The results obtained are discussed for all the provinces as defined by M.L. Ramenskaya (1960: see Fig. 40).

Results. Paanajärvi National Park is located in the Northwestern floristic province (I, Fig. 40) which forms the eastern part of the *Kuusamo* biogeographic province as defined by Scandinavian naturalists (Mela & Cajander, 1906). Pioneer studies of mosses were carried out in this area by Finnish botanists as early as the 19th century and their results were summarised by the well-known bryologists V. Brotherus (1923) and R. Tuomikoski (1939). Over the past few years Russian (Maksimov, 1995) and Finnish (Halonen & Ulvinen, 1996) scientists have drawn up lists of mosses. The annotated list presented for the park by A.I. Maksimov (1995) consists of 275 species (from here onwards, the nomenclature of mosses follows that established by M.S. Ignatov and O.M. Afonina, 1992) and contains eight species additional to the list made up by L.A. Volkova and A.I. Maksimov (1993) for floristic province I. More recently, P. Halonen & T. Ulvinen (1996) added a further 14 species and one subspecies (Table 17). *Bryum rutilans, Drepanocladus tenuinervis, Gymnostomum boreale* and *Pohlia andalusica* are species not reported earlier from any

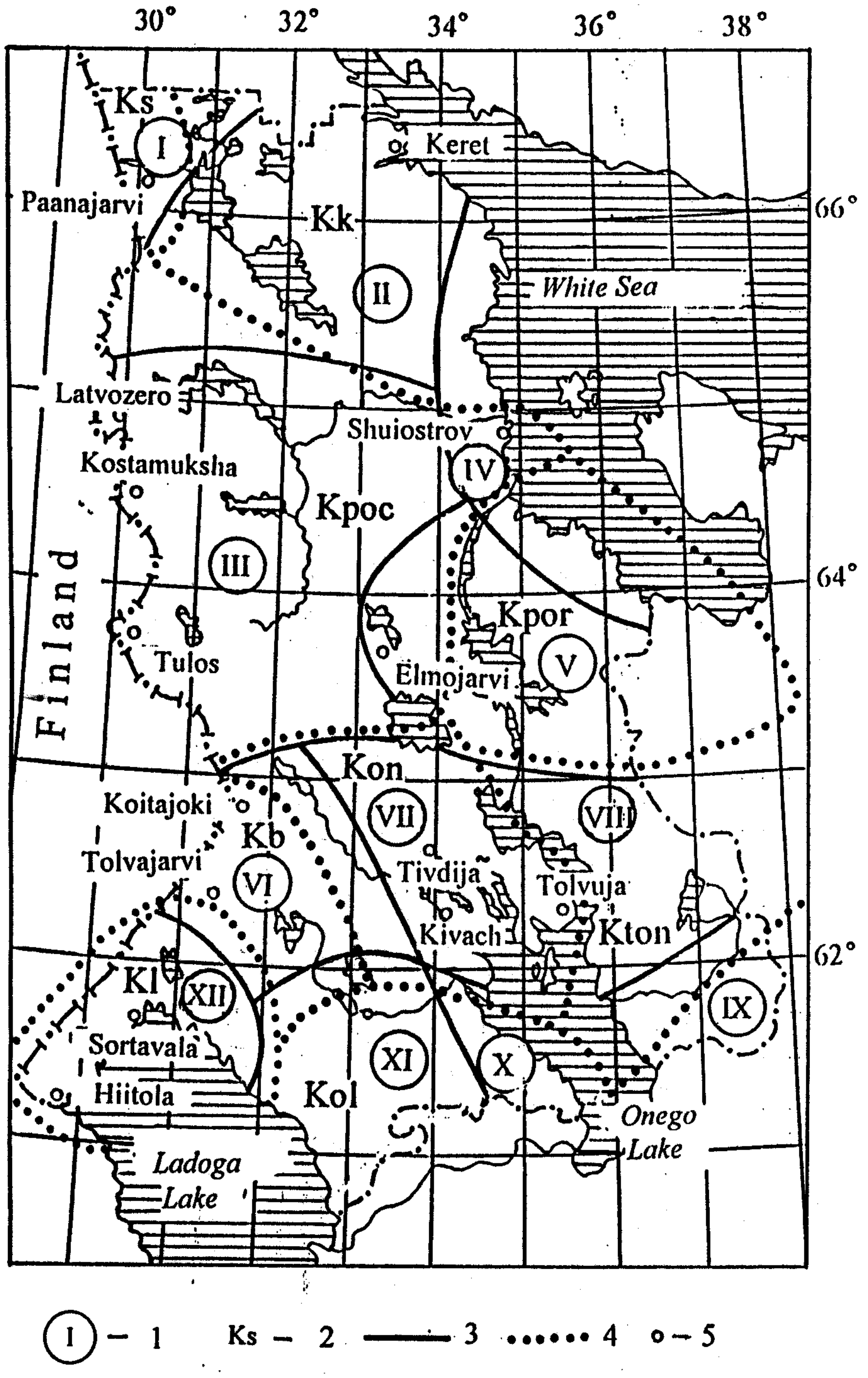


Fig. 40. Map of the floristic and biogeographic provinces of Karelia and the geographic position of study areas

1 = numbers of floristic provinces (after Ramenskaya, 1960); 2 = abbreviations used for the biogeographic provinces Mela & Cajander (1906); 3 = boundaries of the floristic provinces; 4 = boundaries of the biogeographic provinces; 5 = strictly protected areas studied and local bryofloras.

Floristic provinces: I = Northwestern montane province; II = Topozero-Keretozero province; III = Kuitozero-Leksozero province; IV = White Sea province; V = Vygozero province; VI = Zaonezhye province; VIII = Volozero-Vodlozero province; IX = Vodla province; X = Shoksha province; XI = Mezhozerye province; XII = Priladozhye province.

Biogeographic provinces: *Ks = Kuusamo, Kk = Karelia keretina, Kpoc = Karelia pomorica occidentalis, Kpor = Karelia pomorica orientalis, Kb = Karelia borealis, Kon = Karelia onegensis, Kton = Karelia transonegensis, Kol = Karelia olonetsensis, Kl = Karelia ladogensis* part of Karelia. Analysis of the herbarium collected by A.I.Maksimov during the period 1988–1997 revealed nine species and one variety not previously found in the park (Table 17). These additions bring the known population of moss species in the park to 298. As almost all bryofloristic studies of the Northwestern floristic province have been conducted in the area of the park the species composition of the mosses known for this province is based on the above data (Table 18).

Characteristic of the park is the occurrence of certain southern species not found at the same latitude in adjacent regions. These include *Anomodon viticulosus, A. longifolius, Brachythecium velutinum, Orthodicranum flagellare, Plagiomnium rostratum,* and *P. elatum*. According to R. Tuomikoski (1939) the sites inhabited by *Didymodon fallax var. reflexus, Neckera crispa, Orthodicranum flagellare* and some other species are the northernmost locations not only in East Fennoscandia but also for the whole of Fennoscandia. Thus, finds in Paanajärvi National Park of rare arctomontane species such as *Bryum arcticum, Grimmia montana, Gymnostomum boreale, Hypnum hamulosum, Plagiobryum zieri* and *Pohlia obtusifolia* represent the only recordings of these species for the whole of Fennoscandia. Forty-two rare mosses listed in RDBK and RDBEF are known to grow in the park (Table 19). Fourteen species occurring in the park have not been encountered elsewhere in Karelia. A. I. Maksimov's herbaria have confirmed the occurrence of four rare species, namely *Hypnum vaucheri, Rhynchostegium riparioides, Seligeria brevifolia* and *Tayloria lingulata*. Many rare species characteristically grow on the rocks and in the tundra belt of the park's highest mountains such as Nuorunen and Kivakka. The phytocenoses in which they occur are sensitive and can easily be destroyed by tourism. This should be taken into account when laying out hiking paths in the park.

The moss flora of the **Keret** Reserve, which takes in the Keret, Kishkin and Sidorov Islands in the White Sea, was studied by A.I. Maksimov in August 1998. The reserve is located in the Topozero-Keretozero floristic province (II) which almost completely overlaps the biogeographic province of *Karelia keretina* (Fig. 40). Until recently it had been considered to possess only a poor bryoflora with L.A.Volkova and A.I.Maksimov (1993) detailing only 119 moss species. However, a study in the Kem-luda Archipelago conducted by O.A.Belkina and A.Y.Likhachev (1997; 1999) revealed 151 species, including 66 new species and 4 new varieties for the floristic province (Table 17). Eight species and one variety, i.e. *Bryum intermedium, B. oblongum, B. salinum, Dicranum groenlandicum, D. muehlenbeckii, Orthotrichum affine, O. pylaisii, Polytrichum longisetum var. anomalum, Warnstorfia pseudostraminea* are recorded for the first time for the whole of Karelia.

Bryum oblongum, B. rutilans, Hamatocaulis vernicosus and *Pseudoleskeella papillosa* are listed in the Red Data Book of Europe (1995), and *Warnstorfia pseudostraminea, Barbula unguiculata, Brachythecium velutinum* and *Dicranum spurium* are included in the Red Data Book of the Murmansk Oblast (Rare …, 1990). Eleven rare moss species found in Kem-ludasare are listed in RDBK and RDBEF (Table 19).

Our studies carried out in 1998 in the Keret Reserve revealed 129 moss taxa (Maksimov & Maksimova, 1999). On analysis of our herbarium four further species, *Amphidium lapponicum, Eurhynchium pulchellum, Hamatocaulis vernicosus* and *Tortella fragilis,* were identified. We added 16 new species and 2 new varieties (Table 17) for the Topozero-Keretozero floristic province (II). Of these *Polytrichastrum alpinum var. fragile* and *Sanionia orthothecioides* are new for the whole of Karelia. L. Hedenäs (1989) was the first to report *Sanionia orthothecioides* from the eastern part of *Karelia keretina* province but the exact location was not specified. Two moss species, *Aulacomnium turgidum* and *Brachythecium turgidum*, are included in RDBK and RDBEF. There are a greater number of arctmontane and hypoarctic-montane moss species in the Keret Reserve than on the mainland because the reserve is located on an island. The diversity of bryophytes (133 taxa or 129 species) and the presence of calciphilous species in the Keret Reserve are due to the presence of quartz-carbonate veins in the granite gneiss rocks occurring on the islands (Volodichev, Stepanov, Lukashov, 1999). The Keret reserve hosts many of the species occurring in the Topozero-Keretozero floristic province (67%), as well as *Aulacomnium turgidum* and *Brachythecium turgidum* that are listed in RDBK and RDBEF, and is therefore a site considerable bryofloristic importance.

Study of the Kem-luda Archipelago and the Keret Reserve has led to the identification of 201 moss species for floristic province II (Table 18, Fig. 40).

The **Kostomuksha** Strict Reserve and the proposed **Kalevala** and **Tuulos** national parks are located in the Kuitozero-Leksozero floristic province (III) which partly overlaps the biogeographic province of *Karelia pomorica occidentalis* (Fig. 40).

Mosses were studied in the proposed **Kalevala** National Park in 1997 near the villages of Sudnozero, Latvozero (Boichuk, 1998; Kuznetsov et al., 2000) and Labuka (collections of O.L.Kuznetsov and A.V. Kravchenko, 2000). The data obtained indicates that the bryoflora of the park consists of 162 moss species, i.e. 69% of the total bryoflora of floristic province III. Seventeen species are reported for the province for the first time (Table 17) while two species, *Dicranella rufescens* and *Oligotrichum hercynicum*, had not been reported earlier anywhere in Karelia (Boichuk, 1998). Six species, namely *Dicranella rufescens, Discelium nudum, Fontinalis squamosa, Pseudotaxiphyllum elegans, Sphagnum denticulatum* and *Warnstorfia pseudostraminea*, are listed in RDBK and RDBEF.

The moss flora of the **Kostomuksha** Strict Nature Reserve was studied in 1995-1998 (Boichuk, 2001). According to the study the reserve has 159 moss species that account for 68% of all the mosses known in floristic province III. Twelve species are new for province III (Table 17) while three species, *Dicranella palustris, Hygrohypnum smithii* and *Ulota crispa*, are new for the whole of Karelia. Rare and protected mosses include *Sphagnum denticulatum, S. subnitens, Fontinalis squamosa* and *Warnstorfia pseudostraminea*.

Table 17

List of new mosses in the floristic regions of Karelia

Species	Floristic regions									
	I	II	III	IV	V	VI	VII	X	XI	XII
Amblystegium serpens (Hedw.) Schimp. in B.S.G.	+	+*								
A. serpens var. juratzkanum (Schimp.) Rau et Herv.		+								
Amphidium lapponicum (Hedw.) Schimp.		+								
Anoectangium aestivum (Hedw.) Mitt.										+*
Atrichum undulatum (Hedw.) P. Beauv.						+				
Aulacomnium turgidum (Wahlenb.) Schwaegr.		+*								
Barbula unguiculata Hedw.		+*								
Bartramia ithyphylla Brid.		+								
Brachythecium albicans (Hedw.) Schimp. in B.S.G.		+*		+		+				
B. campestre (C. Muell.) Schimp. in B.S.G.		+*	+*							+
B. erythrorrhizon Schimp. in B.S.G.						+				
B. mildeanum (Schimp.) Schimp. ex Milde	+	+*		+	+	+				
B. oedipodium (Mitt.) Jaeg.		+*				+				
B. plumosum (Hedw.) Schimp. in B.S.G.			+*			+				
B. populeum (Hedw.) Schimp. in B.S.G.		+*								
B. rivulare Schimp. in B.S.G.						+				
B. rutabulum (Hedw.) Schimp. in B.S.G.			+*							
B. starkei (Brid.) Schimp. in B.S.G.		+*	+*			+				
B. turgidum (Hartm.) Kindb.		+*		+						
B. velutinum (Hedw.) Schimp. in B.S.G.		+*				+				
Bryoerythrophyllum recurvirostre (Hedw.) Chen						+				
Bryum argenteum Hedw.		+*	+*			+				
B. caespiticium Hedw.						+				
B. creberrimum Tayl.	+*	+*	+*							
B. elegans Nees ex Brid.	+	+*								
B. imbricatum (Schwaegr.) Bruch et Schimp. in B.S.G.		+*	+*							
B. intermedium (Brid.) Bland.		+*								
B. oblongum Lindb.		+*								
B. pallens (Brid.) Sw. ex Roehl.	+*									
B. rutilans Brid.	+*	+*								
B. salinum Hag. ex Limpr.		+*		+						
B. stirtonii Bruch et Schimp. in B.S.G.										+*
B. weigelii Spreng. in Biehler		+								
Callicladium haldanianum (Grev.) Crum						+				
Calliergon giganteum (Schimp.) Kindb.		+*								
C. megalophyllum Mikut.			+*							
C. richardsonii (Mitt.) Kindb. in Warnst.		+*								
Calliergonella cuspidata (Hedw.) Loeske			+*							
Camptothecium lutescens (Hedw.) Schimp. in B.S.G.										+*
Campylium calcareum Crundw. et Nyh.							+			+
C. polygamum (B.S.G.) C. Jens.		+*			+					
C. radicale (P. Beauv.) Grout										+*
C. sommerfeltii (Myr.) J. Lange	+*	+*				+				
Cinclidium stygium Sw.		+*			+					
C. subrotundum Lindb.				+						
Cirriphyllum piliferum (Hedw.) Grout		+								
C. thommasinii (Boul.) Grout							+			
Cnestrum schistii (Web. et Mohr) Hag.			+*							
Cynodontium tenellum (Bruch et Schimp.) Limpr.		+*				+				
Dicranella heteromalla (Hedw.) Schimp.						+				
Dicranella palustris (Dicks.) Crundw. ex E. Warb.			+*							
D. rufescens (Dicks.) Schimp.			+*							
D. schreberiana (Hedw.) Hilp. ex Crum et Anderson	+*									
Dicranum brevifolium (Lindb.) Lindb.		+		+						
D. drummondii C. Muell.		+*		+						
D. fragilifolium Lindb.						+				
D. groenlandicum Brid.		+*								
?D. muehlenbeckii Bruch et Schimp. in B.S.G.		+*								
D. spurium Hedw.		+*				+				
Didymododon rigidulus Hedw.							+			
Discelium nudum (Dicks.) Brid.			+*							

Species	Floristic regions									
	I	II	III	IV	V	VI	VII	X	XI	XII
Ditrichum flexicaule (Schwaegr.) Hampe		+*								
Drepanocladus aduncus (Hedw.) Warnst.			+*		+	+				
D. aduncus var. capillifolius (Warnst.) Riehm.	+*									
D. tenuinervis T. Kop.	+*									
Eurhynchium hians (Hedw.) Sande Lac.							+			
E. pulchellum (Hedw.) Jenn.		+								
E. pulchellum var. praecox (Hedw.) Dix.	+									
Fissidens adianthoides Hedw.		+*								
F. bryoides Hedw.								+		
F. osmundoides Hedw.		+*								
F. pusillus (Wils.) Milde								+		
G. donniana Sm.		+*								
Gymnostomum boreale Nyholm et Hedenaes.	+*									
Hamatocaulis vernicosus (Mitt.) Hedenaes		+	+*							
Helodium blandowii (Web. et Mohr) Warnst.		+*		+						
Hygroamblystegium fluviatile (Hedw.) Loeske			+*					+		
Hygrohypnum alpestre (Hedw.) Loeske			+*							
H. smithii (Sw. ex Lilj.) Broth.			+*							
Hylocomiastrum pyrenaicum (Spruce) Fleisch. in Broth.			+*							
H. umbratum (Hedw.) Fleisch. in Broth.	+		+*			+	+			
Hymenostylium recurvirostre (Hedw.) Dix.										+*
Hypnum callichroum Funck ex Brid.		+*								
H. cupressiforme Hedw.	+					+				
H. pratense Koch ex Spruce	+*	+*	+*							
H. vaucheri Lesq.										+*
Isopterygiopsis pulchella (Hedw.) Iwats.		+*								
Leptodictyum riparium (Hedw.) Warnst.		+	+*							
Lescuraea saxicola (Schimp. in B.S.G.) Milde		+*								
Leskeella nervosa (Brid.) Loeske						+				
Limprichtia cossonii (Schimp.) Anderson et al.	+	+*	+*							
Mnium ambiguum H. Muell.	+									
M. stellare Hedw.		+								
Myrinia pulvinata (Wahlenb.) Schimp.	+*									
Oligotrichum hercynicum (Hedw.) DC. in Lam. et DC.			+*		+					
Oncophorus virens (Hedw.) Brid.		+*								
O. wahlenbergii Brid.						+				
Orthothecium chryseon (Schwaegr. ex Schultes) Schimp. in B.S.G.										+*
Orthotrichum affine Brid.		+*								
O. obtusifolium Brid.		+*				+				
O. pylaisii Brid.		+*								
O. rupestre Schleich. ex Schwaegr.						+				
O. speciosum Nees in Sturm	+	+*	+							
Philonotis arnellii Husn.							+			
P. fontana var. pumila (Turn.) Brid.		+*								
Plagiomnium cuspidatum (Hedw.) T. Kop.	+*	+*								
P. elatum (Bruch et Schimp. in B.S.G.) T. Kop.			+*							
P. medium (Bruch et Schimp. in B.S.G.) T. Kop.		+*	+*			+				
P. medium ssp. curvatulum (Lindb.) T. Kop.	+*	+*								
Plagiopus oederiana (Sw.) Crum et Anderson					+					
Plagiothecium cavifolim (Brid.) Iwats.	+					+				
P. latebricola Schimp. in B.S.G.						+				
P. nemorale (Mitt.) Jaeg.							+			+
Platydictya subtilis (Hedw.) Crum						+				
Pogonatum dentatum (Brid.) Brid.		+*				+				+
Pohlia andalusica (Hoehnel) Broth.	+*		+*			+				
P. annotina (Hedw.) Lindb.									+*	
P. bulbifera (Warnst.) Warnst.		+								+
P. obtusifolia (Brid.) L. Koch										+*
P. proligera (Kindb. ex Breidl.) Lindb. ex H. Arnell		+*								+
Polytrichastrum alpinum (Hedw.) G. L. Sm.		+*				+				
P. alpinum var. fragile (Bryhn) Long		+		+						
Polytrichum longisetum var. anomalum (Milde) Hag.		+*	+							
P. swartzii Hartm.						+				

End. table 17

Species	Floristic regions									
	I	II	III	IV	V	VI	VII	X	XI	XII
Pseudocalliergon trifarium (Web. et Mohr) Loeske		+								
Pseudoleskea radicosa (Mitt.) Kindb. in Macoun	+		+*							
Pseudoleskeella papillosa (Lindb.) Kindb.		+*								
P. tectorum (Funck ex Brid.) Kindb. in Broth.		+*				+				
Pseudotaxiphyllum elegans (Brid.) Iwats.			+*							
Pterigynandrum filiforme Hedw.	+	+*								
Pylaisiella polyantha (Hedw.) Grout	+	+*				+				
P. selwynii (Kindb.) Crum et al.										+
Racomitrium aciculare (Hedw.) Brid.			+					+		
R. affine (Schleich. ex Web. et Mohr) Lindb.			+*							
R. canescens (Hedw.) Brid.						+				
R. lanuginosum (Hedw.) Brid.		+*				+				
R. sudeticum (Funck) Bruch et Schimp. in B.S.G.						+				
Rhizomnium magnifolium (Horik.) T. Kop.		+*								
Rhodobryum roseum (Hedw.) Limpr.		+*				+				
Rhynchostegium riparioides (Hedw.) C. Jens.									+	+*
Rhytidiadelphus squarrosus (Hedw.) Warnst.		+*								
R. subpinnatus (Lindb.) T. Kop.		+				+				
Rhytidium rugosum (Hedw.) Kindb.		+*								
Saelania glaucescens (Hedw.) Broth. in Bomanss. et Broth.		+								
Sanionia orthothecioides (Lindb.) Loeske		+		+						
Sarmentypnum sarmentosum (Wahlenb.) Tuom. et T. Kop.		+*			+					
Schistidium agassizii Sull. et Lesq. in Sull.		+				+				
S. apocarpum var. confertum (Funck) Moell.		+*								
S. flaccidum (De Not.) Lindb.		+*								
S. rivulare (Brid.) Podp.	+*					+				
Schistostega pennata Hedw.	+		+*			+				
Seligeria campylopoda Kindb. in Macoun										+*
Sphagnum aongstroemii C. Hartm.						+				
S. compactum DC. in Lam. et DC.						+				
S. cuspidatum Ehrh. ex Hoffm.						+				
S. denticulatum Brid.			+			+				
S. fimbriatum Wils. in Wils. et Hook. f.		+*		+						
S. flexuosum Dozy et Molk.	+		+*			+				
Sphagnum inindatum Russ.						+				
S. isoviitae Flatb.				+						
S. jensenii H. Lindb.						+				+
S. lindbergii Schimp. ex Lindb.						+				
S. molle Sull.						+				+
S. papillosum Lindb.										+
S. platyphyllum (Lindb. ex Braithw.) Sull. ex Warnst.						+				
S. pulchrum (Lindb. ex Braithw.) Warnst.						+	+			
S. quinquefarium (Lindb. ex Braithw.) Warnst.			+			+				
S. riparium Aongst.	+									
S. rubellum Wils.						+				
S. subnitens Russ. et Warnst. ex Warnst.	+		+							
S. tenellum (Brid.) Perss. ex Brid.						+				
S. wanstorfii Russ.				+		+				
S. wulfianum Girg.						+				
Splachnum rubrum Hedw.	+									
S. vasculosum Hedw.										+*
Tayloria lingulata (Dicks.) Lindb.		+*								
T. tenuis (Dicks.) Schimp.	+*	+*								
Thuidium recognitum (Hedw.) Lindb.		+								
Tortella fragilis (Hook. et Wils. in Drumm.) Limpr.		+*								
T. tortuosa (Hedw.) Limp.		+*								
Tortula norvegica (Web. f.) Wahlenb. ex Lindb.					+					
T. ruralis (Hedw.) Gaertn. et al.		+*		+						
Ulota crispa (Hedw.) Brid.			+*							
Warnstorfia pseudostraminea (C. Muell.) Tuom. et T. Kop.		+*	+*			+				
Zygodon viridissimus (Dicks.) Brid.										+*
Total	**31**	**82**	**39**	**14**	**8**	**60**	**8**	**4**	**2**	**22**

* information about mosses in each of the floristic regions reported in available literature: I* – Halonen, Ulvinen (1996); II* – Belkina, Likhachev (1997, 1999); III* – Boichuk (1998, 2001); Kuznetsov et al. (2000) and unpublished data; VII* – Lantratova et al. (2000); Boichuk, Kuznetsov (2000); XI* – Chernyadyeva (1997); XII* – Wahlberg (1998); Huttunen, Wahlberg (1999). Unannotated data reported by Maksimov et al. (1995, 1998a, b); Maksimov, Maksimova (1999, 2000) and unpublished material.

Table 18

The number of mosses in the floristic provinces of Karelia

Floristic provinces	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Karelia
Number of species (after Volkova and Maksimov, 1993)	267	119	196	121	191	131	305	140	141	182	177	339	415
Number of new species according to 1993–2000 studies	31	82	39	14	8	60	8	0	0	4	2	22	
Total as of 2000	298	201	235	135	199	191	313	140	141	186	179	361	442
Number of rare spesies included in RDBK and RDBEF	42	13	8	4	1	3	25	1	5	5	6	68	109
New species found in Karelia	4	8	5	2	0	0	2	0	0	1	1	5	28

Outside of the reserve in the vicinity of Kostomuksha 123 moss species, including 6 species not previously reported for the province, i.e. *Bryum argenteum, B. imbricatum, Calliergonella cuspidata, Hylocomiastrum pyrenaicum* and *Pseudoleskea radicosa*, were identified.

The Kostomuksha Strict Reserve together with the Kostomuksha area possess a total of 174 moss species (74% of species known for the province). Taken together with the proposed Kalevala National Park, these figures rise to 194 species and 82% respectively. Of these only one species *(Hygrohypnum ochraceum*) out of 194 was previously listed in available literature (Makirinta et al., 1997) while just two species (*Sphagnum cuspidatum* and *Limprichtia cossonii*) had been identified from the samples collected by G.A.Yelina in 1972 and 1973 (Herbarium of the Institute of Biology, Karelian Research Centre, RAS).

On the basis of studies conducted by A.I.Maksimov in 1997 (Maksimov et al., 1998 b) and analyses of herbaria collected by O.L.Kuznetsov in 2000, the moss flora of the proposed **Tuulos** National Park consists of 105 taxa, i.e. 45% of all moss taxa known for floristic province III. The finds of *Orthotrichum speciosum, Racomitrium aciculare, Sphagnum denticulatum* and *S. quinquefarium* were the first for the province. The taxon *Polytrichum longisetum var. anomalum* (see Annotated List) was reported for the first time in Karelia. *Sphagnum denticulatum, S. subnitens* are listed in RDBK and RDBEF.

To sum up, the moss studies of the proposed Kalevala and Tuulos national parks, the Kostomuksha Strict Reserve and the Kostomuksha area have led to the identification of 195 moss species, i.e. 83% of the bryoflora of floristic province III. Thirty-nine species are new to the province and five species and one variety new to the whole of Karelia (Table 17, Annotated List). The moss flora of the Kuitozero-Leksozero floristic province, and therefore of the biogeographic province of *Kpoc* is now known to contain a total of 235 species (Table 18, Fig. 40). Characteristic of the protected areas studied is the presence of western and Atlantic species such as *Racomitrium aciculare, R. affine, Sphagnum denticulatum, S. rubellum, S. subnitens, S. tenellum* and *S. quinquefarium*. The bryoflora of these areas is poorer than for floristic province III as a whole due to the occurrence of poor felsic bedrock.

The **Shuiostrovsky** Reserve is located in the White Sea floristic province (IV), which forms the eastern part of the biogeographic province of *Karelia pomorica occidentalis*. This province has a very poor bryoflora with just 121 species (Table 17), barely 30% of Karelia's total moss flora. Studies conducted by A.I. Maksimov in 1998 on Shuiostrov and Bolshoi Sosnovets Islands revealed 62 moss species. Thirteen species and one variety were found for the first time in floristic province IV (Table 17) while *Sphagnum isoviitae* is new for Karelia as a whole. Thus, the moss flora of floristic province IV is now known to contain 134 species. *Polytrichastrum alpinum var. fragile*, found on Bolshoi Sosnovets Island is quite a rare taxon and occurs sporadically on rocky islands in the White Sea. Also found here is an arctomontane form of the common species *Sanionia uncinata (S. uncinata f. gracilescens*).

The small number of moss species in the Shuiostrovsky Reserve is most probably due to the relatively recent origination of its islands (i.e. from the Sub-Atlantic period), large-scale paludification and the relative lack of exposed bedrock outcrops. The results of our studies agree with those obtained by R.R. Pole (1915) who recorded 38 moss species for the Kuzova Archipelago which is situated near the Shuiostrovsky Reserve.

In 2000, A.I. Maksimov and T.A. Maksimova studied mosses near Lake Yelmozero in the Vygozero floristic province (V) (Fig. 40) and found 8 new species, *Brachythecium mildeanum, Campylium polygamum, Cinclidium stygium, Drepanocladus aduncus, Oligotrichum hercynicum, Plagiopus oederiana, Sarmentypnum sarmentosum* and *Tortula norvegica*. The last mentioned is a rare species listed in RDBK and RDBEF. and was previously known only from Vodlozersky National Park (Volkova & Maksimov, 1993).

During 1995–1998 we studied mosses in the proposed **Koitajoki** National Park and the **Tolvajärvi** Landscape Reserve (Maksimov et al., 1998 a, b). Some interesting findings were made by O.L. Kuznetsov in 1999. To sum up, 157 moss species (98 species in Koitajoki National Park and 141 in the Tolvajärvi Reserve) were identified. This corresponds to 82% of all moss species known for the Suna-Suojärvi floristic province (VI) located in the eastern part of the biogeographic province of *Karelia borealis.* No less than sixty species were reported for the province for the first time (Table 17).

Two new moss species previously unknown in Karelia were identified. *Pohlia andalusica* was found in the Tolvajärvi Reserve and *Warnstorfia pseudostraminea* in the proposed Koitajoki National Park. *Pohlia andalusica* was first reported from Karelia during a study of Paanajärvi National Park (Halonen & Ulvinen, 1996) while *Warnstorfia pseudostraminea* was found in the Kem-luda Archipelago (Belkina & Likhachev, 1997). These two species were identified more recently in the proposed Kalevala National Park and the Kostomuksha Strict Reserve (*Kuznetsov et al.,*

Table 19

Occurrence in the protected areas of Karelia of rare mosses included in the Red Data Book of East Fennoscandia

Species	Categories	Occurrence in the Protected areas
Andreaea obovata Thed.	3 (R)	PNP
Antitrichia curtipendula (Hedw.) Brid.	3 (R)	LPNP
Arctoa fulvella (Dicks.) Bruch et Schimp. in B.S.G.	3 (R)	PNP
Atrichum flavisetum Mitt.	3 (R)	LPNP
Aulacomnium turgidum (Wahlenb.) Schwaegr.	3 (R)	PNP, K-l, KR
Barbula unguiculata Hedw.	3 (R)	K-l, LPNP
Brachythecium turgidum (Hartm.) Kindb.	3 (R)	PNP, K-l, ShR, KR
Bryum arcticum (R. Br.) Bruch et Schimp. in B.S.G.	3 (R)	PNP
B. rutilans Brid.	3 (R)	PNP, K-l
Campylium calcareum Crundw. et Nyh.	3 (R)	LPNP
C. halleri (Hedw.) Lindb.	3 (R)	PNP, LPNP
Cinclidium subrotundum Lindb.	3 (R)	PNP, K-l
Coscinodon cribrosus (Hedw.) Spruce	2 (V)	LPNP
Ctenidium molluscum (Hedw.) Mitt.	3 (R)	KiSR
Desmatodon latifolius (Hedw.) Brid.	3 (R)	PNP, LPNP
Dicranella humilis Ruthe	3 (R)	PNP
D. rufescens (Dicks.) Schimp.	3 (R)	KPNP
Didymodon icmadophyllus (Schimp. ex C. Muell.) Saito	3 (R)	PNP
D. rigidulus Hedw.	3 (R)	PNP, KiSR
Diphyscium foliosum (Hedw.) Mohr	3 (R)	PNP
Discelium nudun (Dicks.) Brid.	3 (R)	KPNP
Distichium inclinatum (Hedw.) Bruch et Schimp. in B.S.G.	3 (R)	PNP
Dryptodon patens (Hedw.) Brid.	3 (R)	LPNP
Encalypta mutica Hag.	3 (R)	PNP
E. procera Bruch	3 (R)	PNP
Eurhynchium praelongum (Hedw.) Schimp. in B.S.G.	3 (R)	LPNP
Fontinalis squamosa Hedw.	3 (R)	KPNP, KoSR
Grimmia anodon Bruch et Schimp. in B.S.G.	3 (R)	LPNP
G. donniana Sm.	3 (R)	PNP, K-l
G. elatior Bruch ex Bals. et De Not.	3 (R)	LPNP
G. hartmannii Schimp.	3 (R)	LPNP
G. incurva Schwaegr.	3 (R)	PNP
G. montana Bruch et Schimp. in B.S.G.	3 (R)	PNP
G. unicolor Hook. in Grev.	3 (R)	LPNP
Gymnostomum boreale Nyh. et Hedenaes	2 (V)	PNP
Hamatocaulis lapponicus (Norrl.) Hedenaes	3 (R)	LPNP
Herzogiella striatella (Brid.) Iwats.	3 (R)	LPNP
Homalia besseri Lob.	3 (R)	LPNP
Hymenostylium recurvirostre (Hedw.) Dix.	3 (R)	PNP, LPNP
Hypnum callichroum Funck ex Brid.	3 (R)	PNP, K-l
H. hamulosum Schimp. in B.S.G.	3 (R)	PNP
H. vaucheri Lesq.	3 (R)	PNP
Myrinia pulvinata (Wahlenb.) Schimp.	2 (V)	PNP
Myurella tenerrima (Brid.) Lindb.	3 (R)	PNP
Neckera crispa Hedw.	3 (R)	PNP, LPNP
N. pennata Hedw.	3 (R)	KiSR, LPNP
Orthothecium chryseon (Schwaegr. ex Schultes) Schimp. in B.S.G.	3 (R)	PNP, LPNP
O. rufescens (Brid.) Schimp. in B.S.G.	3 (R)	PNP
Orthotrichum pallens Bruch ex Brid.	3 (R)	LPNP
O. urnigerum Myr.	0 (Ex)	LPNP
Philonotis arnellii Husn.	3 (R)	LPNP
P. *fontana var. falcata* (Hook.) Brid.	4 (I)	PNP
Physcomitrium sphaericum (Ludw.) Brid.	3 (R)	LPNP
Plagiobryum zieri (Hedw.) Lindb.	3 (R)	PNP
Plagiomnium drummondii (Bruch et Schimp.) T. Kop.	3 (R)	KiSR, LPNP
Platydictya confervoides (Brid.) Crum	3 (R)	LPNP
Platygyrium repens (Brid.) Schimp. in B.S.G.	4 (I)	LPNP
Pleuridium subulatum (Hedw.) Rabenh.	3 (R)	LPNP
Pohlia obtusifolia (Brid.) L. Koch	3 (R)	PNP
Polytrichum formosum Hedw.	3 (R)	LPNP
P. hyperboreum R. Br.	3 (R)	PNP

Species	Categories	Occurrence in the Protected areas
Pseudotaxiphyllum elegans (Brid.) Iwats.	3 (R)	KPNP, LPNP
Racomitrium heterostichum (Hedw.) Brid.	3 (R)	TR, LPNP
Rhabdoweisia fugax (Hedw.) Bruch et Schimp. in B.S.G.	3 (R)	LPNP
Rhynchostegium riparioides (Hedw.) C. Jens.	3 (R)	PNP
Schistidium flaccidum (De Not.) Lindb.	3 (R)	K-l, LPNP
Seligeria brevifolia (Lindb.) Lindb.	3 (R)	PNP
S. donniana (Sm.) C. Muell.	3 (R)	PNP
S. subimmersa Lindb.	1 (E)	PNP
S. tristichoides Kindb.	3 (R)	PNP
Sphagnum denticulatum Brid.	3 (R)	KoSR, TPNP, TR, KPNP
S. molle Sull.	2 (V)	KoPNP
S. subnitens Russ. et Warnst. ex Warnst.	4 (I)	PNP, KoSR, TPNP
Splachnum vasculosum Hedw.	3 (R)	PNP, K-l
Tayloria lingulata (Dicks.) Lindb.	3 (R)	PNP, K-l
T. splachnoides (Schleich. ex Schwaegr.) Hook.	3 (R)	PNP
Tortula mucronifolia Schwaegr.	3 (R)	PNP
Ulota hutchinsiae (Sm.) Hammar	3 (R)	LPNP
Warnstorfia pseudostraminea (C. Muell.) Tuom. et T. Kop.	4 (I)	K-l, KPNP, KoSR, KoPNP

Abbreviation, categories and symbols used in Table: 0 = Extinct, 1 = Endangered, 2 = Vulnerable, 3 = Rare, 4 = Declining, PNP = Paanajärvi NP, K-l = Kem-ludas (Kandalaksha Strict Reserve), KR = Keret Reserve, KPNP = Kalevala PNP, KoSR = Kostomuksha Strict Reserve, TPNP = Tulos PNP, ShR = Shuiostrov Reserve, KoPNP = Koitajoki PNP, TR = Tolvojärvi Reserve, KiSR = Kivach Strict Reserve, LPNP = Ladoga Skerries PNP

2000). Of utmost interest are epiphytic mosses growing on aspen (*Pylaisiella polyantha, Orthotrihum speciosum, O. obtusifolium, Ptilidium pulcherrimum* and *Radula complanata*) as almost all of these types of woody plants have been cut down in Finland.

The proposed Koitajoki National Park hosts a unique bryoflora containing some Atlantic species, i.e. *Racomitrium aciculare, Sphagnum molle, S. pulchrum, S. tenellum* and *S. quinquefarium*, and two Red Data Book species: *Warnstorfia pseudostraminea* and *Sphagnum molle*. This last-mentioned is very scarce in East Fennoscandia as well as being the rarest sphagnum moss in Russia.

In addition to the occurrence of the Red Data Book species *Sphagnum denticulatum*, the Tolvajärvi Landscape Reserve has fragments of spruce forests with typical bryoflora, including some old-growth forest indicator species such as *Hylocomiastrum umbratum, Rhodobryum roseum, Rhytidiadelphus subpinnatus, Sphagnum quinquefarium, S. wulfianum, Calypogeia suecica, Lophozia longiflora var. guttulata* and *L. ascendens*. The presence of these bryophytes indicate that the mature spruce stands growing in the reserve are old-growth.

The bryoflora of the **Kivach** Strict Nature Reserve, one of Karelia's oldest protected areas, has not been studied for a considerable period of time. The reserve lies in the Zaonezye floristic province (VII) which is much smaller than the biogeographic province of *Karelia onegensis*. Province VII has the second highest number of moss species of all Karelian provinces (Table 18, Fig. 40).

R.R. Pole (1915) was the first to report three moss species from the Kivach Falls area. L. I. Savich-Lyubitskaya (1921) sampled mosses in the reserve in 1920 but it was not until the early 1980s that her collection was analysed by L. A. Volkova. In a well-known review paper on mosses of Fennoscandia, V. Brotherus (1923) reported only 20 species from the reserve. A comprehensive list of Bryophyta consisting of 9 liverwort and 152 moss species was presented by L. A. Volkova in 1981. The results of a study of mire mosses in the reserve were reported by A. I. Maksimov (1983) but it was not until 1995 that an annotated list of 190 mosses from the Kivach Strict Reserve appeared (Maksimov et al., 1995). *Plagiothecium nemorale* was reported for the first time for the whole of Karelia and *Didymodon rigidulus* for the first time for floristic province VII. We analysed the moss herbarium collected by A.V. Kravchenko during 1999–2000 and found four new species, *Brachythecium starkei, Rhytidiadelphus squarrosus, Sphagnum platyphyllum* and *Eurhynchium hians*, this last-mentioned being recorded for the first time for floristic province VII. The new species *Catascopium nigritum* was encountered by A. I. Maksimov while analysing moss herbaria of the 1970s. Thus, the moss flora of the Kivach Strict Reserve is now known to contain 195 species including some rare mosses listed in RDBK and RDBEF such as *Ctenidium molluscum, Didymodon rigidulus, Neckera pennata* and *Plagiomnium drummondii* (Table 19).

A number interesting species was reported from floristic province VII when studying mosses from the Botanical Gardens of the Petrozavodsk State University (Lantratova et al., 2000) and mires in Zaonezhye (Boichuk & Kuznetsov, 2000). 124 moss species were identified in the Botanical Garden. Of these *Cirriphyllum tommasinii* is new species for floristic province VII and together with *Homalia besseri* is listed as a rare species in RDBK and RDBEF. Moss samples collected on mires in Zaonezhye were analysed and *Sphagnum pulchrum*, an amphiatlantic species scarce to southeastern Karelia, was reported for the first time for floristic province VII (Boichuk & Kuznetsov, 2000).

In 2000 A.I. Maksimov and T.A. Maksimova studied mosses near **Tivdia, Ussuna** and **Tolvuya** (Fig. 40) and identified three more species, *Campylium calcareum, Hylocomiastrum umbratum* and *Philonotis arnelli*, previously unknown in floristic province VII. Samples taken confirmed the presence of certain Red Data Book mosses such as *Cirriphyllum tommasinii, Ctenidium molluscum, Didymodon rigidulus, D. icmadophyllus.* As a result of these studies the Zaonezhye district is now known to contain a total of 313 moss species.

Certain mosses not previously reported from the Shoksha (X) floristic province, i.e. *Racomitrium aciculare, Hygroamblystegium fluviatile, Fissidens bryoides var. gymnandrus* and *F. pusillus*, were encountered by A.I. Maksimov and T.A. Maksimova (1996, 1998) during studies of Lososinka river mosses in the green belt of Petrozavodsk. The reporting of the last-mentioned species was the first for the whole of Karelia.

Remarkable for the diversity of its flora, the proposed **Ladoga Skerries** National Park is located in the Priladozhye floristic province (XII) which overlaps the biogeographic province of *Karelia ladogensis* (Fig. 40). Recent data indicates that the province is inhabited by at least 361 moss species (81% of all Karelian bryoflora). 68 of these species are listed as rare in RDBK and RDBEF, with 32 species growing only in northern Priladozhye and not occurring elsewhere in Karelia. In northern Priladozye mosses were studied from the mid 19th century up until the 1940s by many well known Finnish botanists such as W. Nylander, S. O. Lindberg, J. P. Norrlin, V. F. Brotherus, V. Pesola, K. Linkola, M. J. Kotilainen, A. Huuskonen, H. Roivanen, A. Waarama and others. Their results were summarised by V. Brotherus in his review of 1923 and by A. Huuskonen in 1953. Local bryoflora were studied in great detail in the vicinity of Kurkijoki, Lahdenpohja, Sortavala, Kirjavalehti (Ladoga Skerries PNP), Ruskeala and Suistamo (Soanlahti and Leppasyrja). After a considerable period of inactivity research continued in 1997 near Sortavala and Pitkaranta (Huttunen & Wahlberg, 1999). Moss samples were collected in order to confirm the occurrence of certain rare species previously identified by Finnish bryologists. The authors collected six rare moss species, i.e. *Grimmia elatior, G. ovalis, Homalia besseri, Neckera pennata, Orthotricum pallens* and *Pseudotaxiphyllum elegans*. They also found one species, *Camptothecium lutescens*, not previously encountered anywhere in Karelia. In the catalogue of rare Bryophyta sampled in Priladozye and housed in Finnish herbaria H. Wahlberg (1998) drew attention to another twelve species previously unknown for floristic province XII (Table 17, Annotated List).

In August 1999 we studied local bryoflora near Hiitola, Kurkijoki, Sortavala, Kirjavanlahti Bay, Paksuniemi Peninsula and Ristijärvi urochishche in the proposed Ladoga Skerries National Park. The local bryoflora in the proximity of **Hiitola** had not previously been studied to any significant degree. One particular moss species, *Leptobryum pyriforme*, was mentioned by V. Brotherus in 1923 and four species, *Grimmia ovalis, Neckera crispa, Platygyrium repens* and *Ulota hutchinsiae*, were mentioned by H. Wahlberg (1998). Samples of these four species are available for study in Finnish herbaria. Our studies show that the Hiitola area has a total population of 108 moss species (112 species according to available literature) and 2 varieties (Maksimov & Maksimova, 2000). *Mnium hornum* and *Homomallium incurvatum* were excluded from the list after reidentification of the specimens in question. Nine mosses from Hiitola are listed in RDBK and RDBEF: *Grimmia ovalis, Neckera crispa, N. pennata, Platygyrium repens, Pseudotaxiphyllum elegans, Ulota hutchinsiae, Racomitrium heterostichum, Rhabdoweisia fugax* and *Coscinodon cribrosus*. The last three of these species are very rare in Karelia. So far neither *Rhabdoweisia fugax,* nor *Coscinodon cribrosus* has been encountered elsewhere in the proposed park. According to the collections made by A.J. Huuskonen in 1935 Leppasyrja was the only known site of *Rhabdoweisia fugax*. Likewise, *Coscinodon cribrosus* had only been found by W. Nylander in 1844 on Valaam Island (Brotherus, 1923; Wahlberg, 1998) while *Racomitrium heterostichum* was known from samples taken in 1874 in Kirjavalahti by J.P. Norrlin and also from Valaam from the collections of an unknown author who did not indicate a sampling date (Brotherus, 1923; Wahlberg, 1998).

The proposed Ladoga Skerries National Park has a total of 233 moss species not including Sphagnum mosses (Brotherus, 1923; Huttunen & Wahlberg, 1999 et al.). As a result of our studies carried out in 1999 a further 36 moss species, namely *Abietinella abietina, Bartramia pomiformis, Brachythecium campestre, B. mildeanum, Campylium polygamum, Ceratodon purpureus, Coscinodon cribrosus, Dicranella crispa, D. heteromalla, D. schreberiana, Dicranum majus, Leptodictyum humile, Orthotrichum obtusifolium, Plagiomnium ellipticum, Plagiothecium nemorale, Pohlia bulbifera, P. proligera, Pseudobryum cinclidioides, Pylaisiella selwynii, Schistostega pennata, Sphagnum angustifolium, S. capillifolium, S. centrale, S. fallax, S. fuscum, S. girgensohnii, Sphagnum jensenii, S. majus, S. papillosum, S. quinquefarium, S. riparium, S. russowii, S. squarrosum, S. subsecundum, S. teres* and *S. wulfianum,* were identified. Eight species were found for the first time in the *Karelia Ladogensis* province (Table 17). Another locality of *Plagiothecium nemorale* is the Kivach Strict Reserve. All the Sphagnum mosses we identified in the proposed Ladoga Skerries National Park must be considered as new finds as previous recordings in existing literature for floristic province XII (Isoviita, 1970; Volkova & Maksimov, 1993) were made without any indication of sampling sites. The proposed park is now known to contain a total of 269 moss species (75% of the total moss flora of *Karelia Ladogensis* province). Thirty-four rare species listed in RDBK and RDBEF occur in the park (Huttunen & Wahlberg, 1999; Maksimov, 2000; Table 19). Our sampling provided further evidence for the occurrence of seven rare species: *Coscinodon cribrosus, Neckera pennata, Orthotrichum urnigerum, Platygyrium repens, Pseudotaxiphyllum elegans, Racomitrium heterostichum* and *Rhabdoweisia fugax*.

From the bryofloristic point of view the establishment of a Ladoga Skerries National Park is of considerable importance as at present there exists no large protected area within the biogeographic province *Kl* in spite of the fact that this is the most floristically diverse province in the whole of Karelia.

Conclusion. The results of both earlier and recent (1997–2000) bryofloristic studies in Karelia were analysed and lists of mosses were drawn up for most protected areas including the Kivach and Kostomuksha Strict Nature Reserves, the Paanajärvi National Park, the proposed Kalevala, Ladoga Skerries, Koitajoki and Tuulos national parks, and the Tolvajärvi, Keret and Shuiostrovsky reserves. With the exception of the Kivach Strict Reserve, Paanajärvi National Park and the proposed Ladoga Skerries National Park these were the first moss studies undertaken for the areas in question. Local moss flora occur in all major types of ecosystems known to Karelia, i.e. forests, mires, grasslands and water bodies. The number of moss species found in the strictly protected areas investigated account for anything between 14 and 67% of the total number of moss species known for Karelia. It is clear from this that each area possesses its own bryofloristic characteristics (Table 20).

Table 20

Biodiversity of mosses in the protected areas of Karelia
(RDBK - Red Data Book of Karelia; RDBEF - Red Data Book of East Fennoscandia)

Protected areas	Floristic provinces	Number of mosses				
		Total			Included in RDBK and RDBEF	
		number	% of Karelia	% of province	number	% of Karelia
Paanajärvi PNP	I	298	67	100	42	38.5
Kem-ludas (Kandalaksha Strict Reserve)	II	154	35	76	11	10.1
Keret Reserve	II	129	30	64	2	1.8
Kalevala PNP	III	162	37	69	6	5.5
Kostomuksha Strict Nature Reserve	III	159	36	68	3	2.8
Tuulos PNP	III	105	24	45	2	1.8
Shiuostrovsky Reserve	IV	62	14	47	1	1.0
Koitajoki PNP	VI	98	22	52	2	1.8
Tolvajärvi Reserve	VI	141	31	74	2	1.8
Kivach Strict Nature Reserve	VII	195	44	62	4	3.7
Ladoga Skerrier PNP	XII	269	61	75	34	31.0
Total number of moss species in Karelia		442			109	

The species compositions of mosses in the various floristic provinces as described earlier by L.A. Volkova and A.I. Maksimov (1993) was reassessed. Dozens of species were reported from the above protected areas which proved to be first time finds for the floristic (after M.L. Ramenskaya, 1960) and biogeographic (after *Mela & Cajander,* 1906) provinces in question. Additions to the known number of species have been greatest in the Topozero-Keretozero (II) and Suna-Suojärvi (VI) floristic provinces, i.e. 82 and 60 species respectively (Table 18). In all, 27 species and 3 varieties were identified for the first time for the whole of Karelia. These were *Anoectangium aestivum, Bryum intermedium, B. oblongum, B. rutilans, B. salinum, Campthothecium lutescens, Campylium calcareum, C. radicale, Dicranella palustris, D. rufescens, Dicranum groenlandicum, ?D. muehlenbeckii, Drepanocladus tenuinervis, Fissidens pusillus, Gymnostomum boreale, Hygrohypnum smithii, Oligotrichum hercynicum, Orthotrichum affine, O. pylaisii, Plagiothecium nemorale, Pohlia andalusica, P. annotina, Polytrichastrum alpinum var. fragile, Polytrichum longisetum var. anomalum, Plagiomnium medium ssp. curvatulum, Sanionia orthothecioides, Seligeria campylopoda, Sphagnum isoviitae, Ulota crispa* and *Warnstorfia pseudostraminea*. As a result of these new finds the taxonomic list of Karelian mosses now contains a total of 442 species.

Listed in the Red Data Book of Karelia (1995) and the Red Data Book of East Fennoscandia (1998) are 109 species. The largest number of rare Bryophyta occur in Paanajärvi National Park (42 species), in the proposed Ladoga Skerries National Park (36) and in the Kem-luda portion of the Kandalaksha Strict Reserve (11) (Table 20). In all, our collections provided evidence for the occurrence of 31 rare species (28% of all known rare mosses). It should be noted that as the evidence for the presence of many rare species relies upon 100-year-old collections, further studies are needed to support this old data.

Little is known about the mosses of the floristic provinces II, IV, V, VIII and IX as designated by M. L. Ramenskaya (1960) and, correspondingly for the biogeographic provinces *Kb, Kton* and *Kpor*. The Ladoga Skerries National Park needs to be established as soon as possible in order to preserve some of the most diverse bryoflora known to Karelia. In the *Bryophyta* section of the Red Data Book of Karelia (1995), the status of certain moss species must be revised while other new mosses and liverwort species must be added.

Annotated list of rare and newly found moss species in Karelia

**Anoectangium aestivum (*Hedw.) Mitt.– *Kl,* XII: Soanlahti (Wahberg, 1998). RDBEF.

Aulacomnium turgidum (Wahlenb.) Schwaegr. – *Kk,* II: White Sea, Keret Reserve, Sidorov Island, south-facing bedrock exposures, 13 VIII 1998, A. I. Maksimov. RDBK.

Brachythecium glareosum (Spruce) Schimp. In B. S. G. – *Kl,* XII: environs of Ruskeala, abandoned marble open-cast mine, north- and southwest-facing bedrock outcrops and rill of glacial discharge in rocks, marble exposures in fine earth, 4 VIII 1999, A. I. Maksimov & T. A. Maksimova. RDBK, RDBEF.

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* = newly found species; *Kl* etc. = biogeographic provinces, I–XII = floristic provinces, see Fig. 40).

Brachythecium turgidum (Hartm.) Kindb. – *Kpoc,* IV: White Sea, Shuiostrovsky Reserve, Bolshoi Sosnovets Island, southwest- and west-facing gabbroid exposures, moist ravine, in cracks and in fine earth, 6 VIII 1998, A. I. Maksimov. RDBK, RDBEF.

**Bryum intermedium* (Brid.) Bland. – *Kk,* II: Kandalaksha Strict Reserve, Kem-ludas: Izbyanoi Island (Belkina & Likhachev, 1997).

**Bryum oblongum* Lindb. – *Kk*, II: Kandalaksha Strict Reserve, Kem-ludas: Kem-ludsky Island (Belkina & Likhachev, 1997).

**Bryum rutilans* Brid. – *Ks*, I: Paanajärvi NP (*Halonen & Ulvinen,* 1996); *Kk*, II: Kandalaksha Strict Reserve, Kem-ludas (Belkina & Likhachev, 1997). RDBEF.

**Bryum salinum* Hag. ex Limpr. – *Kk*, II: Kandalaksha Strict Reserve, Kem-ludas (Belkina & Likhachev, 1997); Keret Reserve (Maksimov & Maksimova, 1998).

* *Camptothecium lutescens* (Hedw.) Schimp. in B. S. G. – *Kl*, XII: Ladoga Skerries PNP (Huttunen & Wahlberg, 1999).

**Campylium calcareum* Crundw. et Nyh. – *Kl*, XII: Ruskeala, Soanlahti, Leppasyrja (Wahlberg, 1998); Ruskeala area, abandoned marble pit, north-facing bedrock exposures and a rill of glacial discharge in rocks, marble exposures in fine earth. 4 VIII 1999, A. I. Maksimov & T. A. Maksimova. *Kon*, VII: Tivdia area, Krasnaya Gora, western dolomite outcrops, in a deep moist crack together with *Hypnum recurvatum,* 17 VIII 2000, A. I. Maksimov & T. A. Maksimova. RDBEF.

**Campylium radicale* (P. Beauv.) Grout – *Kl,* XII: Ladoga Skerries PNP, Kurkijoki (Wahlberg, 1998).

Cinclidium subrotundum Lindb. – *Kk*, IV: mire «Solnechnoe», 10 km south-west of the village Gridino, small hammock, as admixture to *Campylium stellatum* and *Limprichtia cossonii*, 11 VII 1982, A. I. Maksimov. RDBK, RDBEF.

**Cirriphyllum tommasinii* (Boul.) Grout – *Kon*, VII: Botanical Gardens of the Petrozavodsk State University (Lantratova et al., 2000); Tivdia area, Krasnaya Gora, west-facing dolomite exposures under tree canopy, at the foot of a rock on an a fine earth layer, 18 VI 2000, A. I. Maksimov & T. A. Maksimova. RDBK, RDBEF.

Coscinodon cribrosus (Hedw.) Spruce – *Kl*, XII: Ladoga Skerries PNP, Hiitola area, northwestern end of Rasinselka Bay, southwest-facing steep dry felsic bedrock slightly shaded by pine and birch trees, on fine earth covering rock surface, VII 1999, A. I. Maksimov & T. A. Maksimova, RDBK, RDBEF.

Ctenidium molluscum (Hedw.) Mitt. – *Kon,* VII: Ussuna area, southwest-facing dolomite exposures on the shore of Lake Sundozero, in a wide fissure on rock surface covered by fine earth, 19 VI 2000, A. I. Maksimov & T. A. Maksimova. RDBK, RDBEF.

**Dicranella palustris* (Dicks.) Crundw. ex Warb. – *Kpoc*, III: Kostomuksha Strict Reserve, Kamennaya river bank, in water, 26 VII 1998, M. A. Boichuk.

**Dicranella rufescens* (Dicks.) Schimp. – *Kpoc*, III, Kalevala PNP, village of Sudnozero, in clay ditches, 18 VI 1997, 22 VI 1997, M. A. Boichuk, RDBEF.

**Dicranum groenlandicum* Brid. – *Kk*, II: Kandalaksha Strict Reserve, Kem-ludas (Belkina & Likhachev, 1997).

**? Dicranum muehlenbeckii* Bruch et Schimp in B. S. G. – *Kk*, II: Kandalaksha Strict Reserve, Kem-ludas (Bogdanova, 1969). The occurrence of this species in Karelia is in doubt because the distribution area of *D. muehlenbeckii* does not cover East Fennoscandia (Preliminary distribution ..., 1996).

Didymodon icmadophyllus (Schimp. ex C. Muell.) Saito – *Kon*, VII: Tivdia area, Belaya Gora, abandoned marble pit, steep east-facing rock exposures, wet rock surface, 15 VI 2000, A. I. Maksimov & T. A. Maksimova. RDBEF.

D. rigidulus Hedw.- *Kon*, VII: same environment as for *D. icmadophyllus*, also on dry rock surface; near Ussuna, southwest-facing dolomite outcrops on the shore of Lake Sundozero, on rock surface, 19 VI 2000, A. I. Maksimov & T. A. Maksimova. *Kl*, XII: Ruskeala area, abandoned marble pit, north-facing rock exposures, on marble outcrops covered with fine earth, 4 VIII 1999, A. I. Maksimov & T. A. Maksimova; RDBK, DRBEF.

Discelium nudum (Dicks.) Brid. – *Kpoc*, III, Kalevala PNP, village of Sudnozero, in a clay ditch, 18 VI 1997, M. A. Boichuk; near Sudnozero, in a clay ditch, 23 VI 1997, M. A. Boichuk. RDBK, RDBEF.

**Drepanocladus tenuinervis* T. Kop. – *Ks*, I: Paanajärvi NP (Halonen & Ulvinen, 1996).

**Fissidens pusillus* (Wils.) Milde – *Kol*, X: Petrozavodsk, River Lososinka, on coarse rocks in the river channel, 20 X 1995, 29 X 1995, A. I. Maksimov & T. A. Maksimova. RDBEF.

Fontinalis squamosa Hedw. – *Kk,* III: Kalevala PNP, Latvozero, sq. 188, in the water of Lake Sredneye Latvo, 1997, M. A. Boichuk. RDBK, RDBEF.

**Gymnostomum boreale* Nyholm et Hedenaes. – *Ks*, I: Paanajärvi NP (Nyholm & Hedenäs, 1986; Halonen & Ulvinen, 1996). RDBEF.

**Hygrohypnum smithii* (Sw. ex Lilj.) Broth. – *Kpoc*, III: Kostomuksha Strict Reserve, River Kamennaya (Tsar-porog), on water-covered rocks, 26 VII 1998, M. A. Boichuk.

Hypnum vaucheri Lesq. – *Ks*, I: Paanajärvi NP, Krasnaya Skala (dolomite), on south-facing slopes, 19 IV 1990, A. I. Maksimov. RDBK, RDBEF.

Neckera pennata Hedw. – *Kol*, X: village of Novaya Vilga, green-moss spruce stand mixed with aspen near Sambalskoye Mire, on aspen bark, 24 VIII 1999, A. I. Maksimov & T. A. Maksimova. *Kl*, XII: Ladoga Skerries PNP, near Hiitola, northwestern end of Rasinselka Bay, Oxalis spruce stand with *Hepatica nobilis* on the east-facing slope of a hill, at the foot of aspen trees, VIII 1999, A. I. Maksimov & T. A. Maksimova; 1 km NW of the end of Rasinselka Bay, reedgrass-goutweed-lily of the valley aspen stand on the northeastern slope of a ridge, at the foot of aspen trees, VIII 1999, A. I. Maksimov & T. A. Maksimova. RDBK, RDBEF.

**Oligotrichum hercynicum* (Hedw.) DC. in Lam. et DC. – *Kpoc*, III: Kalevala PNP, Ladvozero area, on the roadside, 10 VIII 1997, M. A. Boichuk; on a 30 km long strip 2 km from the Finnish border, 18 VIII 1997, M. A. Boichuk; Kostomuksha Strict

Reserve, northeastern part, sq. 107, on the roadside, 22 VII 1998, M. A. Boichuk; in the vicinity of Kostomuksha, on the side of an old road leading to Kurkkijärvi, 21 VII 1998, M. A. Boichuk; Tuulos PNP, Vostochny Farm, roadside, 22 VI 2000, O. L. Kuznetsov. *Kpoc*, V: near Lake Yelmozero, Shalgovaary-Kuznavolok, on the side of a road near a recently deforested area, with sporogonia, 11 VIII 2000, A. I. Maksimov & T. A. Maksimova.

**Orthotrichum affine* Brid. – *Kk*, II: Kandalaksha Strict Reserve, Kem-ludas (Belkina & Likhachev, 1997).

**Orthotrichum pylaisii* Brid. – *Kk*, II: same environment as the previous species.

Orthotrichum urnigerum Myr. – *Kl*, XII: Ladoga Skerries PNP, Sortavala: Zaozerny, on southwest-facing rocks, 6 V 1995, A. I. Maksimov. With sporogonia. RDBK, RDBEF.

Philonotis arnellii Husn. – *Kon*, VII: Ussuna, northeastern shore of Lake Sundozero, in a flowing groundwater zone at the foot of a carbonate cliff, on lake shore rocks, 19 VI 2000, A. I. Maksimov & T. A. Maksimova. RDBK, RDBEF.

**Plagiomnium medium spp. curvatulum* (Lindb.) T. Kop. (*Plagiomnium curvatulum* (Lindb.) Schljak.) – *Ks*, I: Paanajärvi NP (*Halonen & Ulvinen*, 1996). *Kk,* II: Kandalaksha Strict Reserve, Kem-ludas (Belkina & Likhachev, 1997).

**Plagiothecium nemorale* (Mitt.) Jaeg. – *Kon*, VII: Kivach Strict Reserve, Lake Munozero (Maksimov et al., 1995). *Kl*, XII: Ladoga Skerries PNP, Paksuniemi peninsula on the north shore of Kirjavalahti Bay, steep north-facing rock under a spruce canopy, on fine earth, 05 VIII 1999, A. I. Maksimov & T. A. Maksimova.

Platygyrium repens (Brid.) Schimp. in B. S. G. – *Kl*, XII: Ladoga Skerries PNP, Ristijärvi urochishche (1.7 km north of Kirjavalahti Bay), on fine earth at the foot of a rock as a small-scale admixture to a sod layer formed by *Brachythecium reflexum*, VIII 1999, A. I. Maksimov & T. A. Maksimova. RDBEF.

* *Pohlia andalusica* (Hoehnel) Broth. – *Kpoc*, III: Kostomuksha Strict Reserve, northern part (end of a fenological itinerary), raised bog, hummock, 3 VIII 1995, M. A. Boichuk; Tuulos PNP, Vostochny Farm, wet shore of Lake Tuulos, 22 VI 2000, O. L. Kuznetsov; northern bank of the River Luzhma, mixed with *Pohlia nutans* on the rocks, 26 VI 2000, O. L. Kuznetsov. *Kb*, VI: Tolvajärvi Reserve, bilberry-green moss spruce stand, the exposed east-facing root of a spruce tree, mixed with *Schistostega pennata*, 27 VII 1998, A. I. Maksimov.

**Pohlia annotina* (Hedw.) Lindb. – *Kol*: XI: Town of Matrosy, Pryazha district (Chernyadyeva, 1997). RDBEF.

**Polytrichastrum alpinum var. fragile* (Bryhn) Long – *Kk*, II: Keret Reserve, Pezheostrov Island, steep cliffs, 11 VIII 1998, A. I. Maksimov. *Kpoc*, IV: White Sea, Shuiostrovsky Reserve, north- and northeast-facing rocks, 3 VIII 1998, A. I. Maksimov.

**Polytrichum longisetum var. anomalum* (Milde) Hag. – *Kpoc*, III: Tuulos PNP, near the village of Tuulos, horsetail-Sphagnum spruce stand, on the exposed root of a spruce tree, 5 VIII 1994, O. L. Kuznetsov.

Pseudephemerum nitidum (Hedw.) Loeske. – *Kol*, XI: village of Kindasovo, Shuya river bank, on exposed clay soil down the southwest-facing slope toward the river, 12 IX 1995; 23 VII 1996, A. I. Maksimov & T. A. Maksimova. RDBK, RDBEF.

Pseudotaxiphyllum elegans (Brid.) Iwats. – *Kpoc*, III: Kalevala PNP, village of Sundozero, on bedrock exposures, 22 VI 1997, M. A. Boichuk. *Kl*, XII: Ladoga Skerries PNP, near the Hiitola, northwestern end of Rasinselka Bay, steep cliffs (southwest-facing felsic rock outcrops) slightly shaded by pine and birch trees, on fine earth covered rocks, VIII 1999, A. I. Maksimov & T. A. Maksimova; 0.5 km northwest of the Paksuniemi Peninsula, Kirjavanlahti Bay, steep SW oriented cliffs facing the bay, the middle portion of a dry slope, on fine earth covered rocks, VIII 1999, A. I. Maksimov & T. A. Maksimova. RDBK, RDBEF.

Racomitrium heterostichum (Hedw.) Brid. – *Kl*, XII: Ladoga Skerries PNP, environs of Hiitola, northwestern end of Rasinselka Bay, steep southwest-facing felsic rock cliffs slightly shaded by pine and birch trees, on fine earth covered rocks, 01 VIII 1999, A. I. Maksimov & T. A. Maksimova; western end of the Kirjavanlahti Bay, Orjatjoki urochishche, steep west-facing cliffs under a coniferous tree canopy, the middle portion of the cliff, on fine earth covered rocks, 06 VIII 1999, A. I. Maksimov & T. A. Maksimova. RDBK, RDBEF.

Rhabdoweisia fugax (Hedw.) Bruch et Schimp. in B. S. G. – *Kl*, XII: near Hiitola, found at the same locality as the previous species, 01 VIII 1999, A. I. Maksimov & T. A. Maksimova. RDBK, RDBEF.

Rhynchostegium riparioides (Hedw.) C. Jens. – *Ks*, I: Paanajärvi NP, northern bank of the River Mantyjoki, 0.5 km from the river mouth, on water-covered rocks, 18 VII 1997, A. I. Maksimov. *Kol*, XI: 6 km northeast of Vidlitsa, River Vidlitsa, on dry rocks in the river channel, 29 VII 1999, A. I. Maksimov & T. A. Maksimova. RDBK, RDBEF.

**Sanionia orthothecioides* (Lindb.) Loeske – *Kpoc*, IV: White Sea, Shuiostrovsky Reserve, Sosnovets Island, a wet ravine on gabbroid exposures, 6 VIII 1998, A. I. Maksimov; Shuiostrov Island, at the coastal grassland-crowberry birch stand boundary, 6 VIII 1998, A. I. Maksimov.

Seligeria brevifolia (Lindb.) Lindb.- *Ks*, I: Paanajärvi NP, Pieni-Nierijaisjärvi, on dolomite outcrops near a mire, 6 VII 1996, A. I. Maksimov. RDBK, RDBEF.

**Seligeria campylopoda* Kindb. in Macoun – *Kl*, XII: Priladozhye, Suistamo (Wahlberg, 1998). RDBEF.

Sphagnum denticulatum Brid. – *Kpoc*, III: Kalevala PNP, near the village of Nizhnyaya Labuka, Lake N. Labuka, in the water at a depth of 0.5 m, 11 VII 2000, O. L. Kuznetsov; Tuulos PNP, west of Lake Tuulos, Aapa-zmeika Mire, outflowing ground water, 6 VIII 1994, O. L. Kuznetsov; Koroppi River flood plain near the village of Tuulos, *Carex lasiocarpa* + *Sphagnum papillosum*, 31 VIII 1997, A. I. Maksimov; in the vicinity of Komettovaara, 3 km south, a creek extending along the engineering facilities, 22 VI 2000. O. L. Kuznetsov; Kostomuksha Strict Reserve, in the proposed extension zone near the northern boundary, lamba shore, in water, 20 VII 1998, M. A. Boichuk; *Kb*, VI; Tolvajärvi Reserve, eastern shore of Lake Hirvasjärvi, 31 VIII 1999, O. L. Kuznetsov; RDBK, RDBEF.

**Sphagnum isoviitae* Flatb. – *Kpor*, IV: White Sea, Shuiostrovsky Reserve, Shuiostrov Island, mesotrophic sedge fen between ombrotrophic and mesotrophic patches in the middle of a mesotrophic mire, 5 VIII 1998, A. I. Maksimov.

**Sphagnum molle Sull.* – *Kb*, VI: Koitajoki PNP, Kuolisma, Lake Kuivajärvi, on a transition bog in molinia-sedge-cotton-grass-Sphagnum cenoses near the shore, 15 VIII 1992, A. I. Maksimov. *Kl*, XII: former Hiisjärvi NP, Lake Hiisjärvi, 10 VII 1998,

A. I. Maksimov; Pitkaranta district, Lake Sargsjärvi, sandy shore, small patches among *Molinia caerulea* in the surf zone, 6 VII 1998, A. I. Maksimov & O. L. Kuznetsov. Red Data Book of the USSR (1984), RDBK, RDBEF.

Sphagnum subnitens Russ. et Warnst. ex Warnst. – *Kpoc*, III: Tuulos PNP, near Lake Tuulos, Aapa-zmeika, springs on the mire margin, 6 VIII 1994, O. L. Kuznetsov; Koroppi river bank, on soil, 29 VII 1997, A. I. Maksimov; Kostomuksha Strict Reserve, near the eastern boundary, paludified bank of the River Munanka, 4 VIII 1995, M. A. Boichuk. RDBK, RDBEF.

Tayloria lingulata (Dicks.) Lindb. – Ks, I: Paanajärvi NP, 14 VIII 1988, A. I. Maksimov. RDBK, RDBEF.

Tortula norvegica (Web. f.) Wahlenb. ex Lindb. – *Kpor*, V: southern shore of Lake Yelmozero, ex-Baranova Gora, lime grass meadow, on soil, 13 VIII 2000, A. I. Maksimov & T. A. Maksimova. RDBK, RDBEF.

**Ulota crispa* (Hedw.) Brid. – *Kpoc*, III: Kostomuksha Strict Reserve, 0.5 km east of Tsar-porog on the River Kamennaya, on a large boulder, 26 VII 1998, M. A. Boichuk.

**Warnstorfia pseudostraminea* (C. Muell.) Tuom. et T. Kop. – *Kpoc*, III: Kalevala PNP, near the village of Sudnozero, bilberry spruce stand growing along the Pridorozhnoye Mire margin, a wet sink, 3 VIII 1995, M. A. Boichuk. *Kb*, VI: Koitajoki PNP, Lake Kangasjärvi, mixed creek-bank forest, a low between the roots of trees, 9 VIII 1997, A. I. Maksimov. RDBEF.

3.3. Aphyllophoroid fungi in forest ecosystems

Introduction. Aphyllophoroid fungi (order Aphyllophorales) form part of the heterotrophic component of forest ecosystems and are essential for their functioning as well as being actively involved in the decomposition and re-synthesis of organic matter. Furthermore, wood-inhabiting macromycetes are recognised as important indicators of the condition of forest ecosystems (Kotiranta & Niemelä, 1996).

The first information concerning aphyllophoroid fungi in East Fennoscandia dates as far back as the late 19th century (Nylander, 1859; Karsten, 1876, 1899). However, the basis for the study of Karelian mycobiota is provided by research performed during the 1920–1924 Olonets Scientific Expedition. This research team analysed material collected and compiled a list of fungi and myxomycetes found in Karelia (Lebedeva, 1933). During the 1930s and 40s a significant contribution to the study of Karelian mycobiota was made by M.V. Freindling (1949). In the 1930s aphyllophoroid fungi were also studied in northwestern Karelia which until 1940 formed a part of the Finnish province Kuusamo. The Finnish mycologist Laurila made up a list of basidiomycetes (Laurila, 1939) with brief descriptions based on his own collections. Laurila identified 16 aphyllophoroid fungus species in Karelia. The most complete review of Karelian fungi was made by V.I. Shubin and V. I. Krutov in their paper “Fungi in Karelia and the Murmansk Region” (1979). This study listed a total of 118 aphyllophoroid fungus species for Karelia. This group of macromycetes was later studied in some detail in the Kivach Nature Reserve (Rodionova, 1973; Bondartseva & Svishch, 1993 and others). Karelia’s aphyllophoroid fungi have long been of interest to Finnish mycologists (Salo, 1986; Lindgren, 1996, 1997a, b, 2001; Niemelä et al., 2001).

Materials and methods. During the period 1992–1999 the present authors analysed a large number of aphyllophoroid fungi sampled from protected areas, in territories to be protected and elsewhere in Karelia. The authors wish to thank L. G. Svishch (Botanical Institute, RAS), S.N. Kiviniemi and A.V. Ruokolainen (Forest Research Institute, KRC, RAS) for making their collections available for analysis. The species composition of aphyllophoroid fungi was mainly studied in the field where their substrates and habitats were identified. Herbaria collected in Russian Karelia and kept in the archives of the mycological herbaria in the V. L. Komarov Botanical Institute (LE), in the Botanical Museum of the Finnish Museum of Natural History, University of Helsinki, Finland (H), and in the Petrozavodsk State University were also examined.

Results. The present survey employed available literature and herbaria as well as our own data. In total, 404 aphyllophoroid fungus species of 150 genera, 44 families and 11 orders were identified for Russian Karelia (Table 21).

Until recently taxonomic analysis of this group of fungi had mainly been based on the system proposed by Donk (Donk, 1964) according to which all aphyllophoroid fungi are classified as belonging to the order *Aphyllophorales* Rea. although the artificial nature of this taxonomic grouping has been repeatedly emphasised by Donk. The idea of subdividing aphyllophoroid fungi into a number of groups was supported by studies of the chemical composition of fungi carried out during the past few years (Hibbert, 1992; Hibbert & Donohue, 1995; Swann & Taylor, 1995; Boidin et al., 1998; Hallenberg & Parmasto, 1998). When taxonomically analysing a group of macromycetes we followed the system set out in the eighth edition of the Ainsworth & Bisby Dictionary of Fungi (Hawksworth et al., 1995) although we also incorporated certain modifications in our approach (Bondartseva, 1998; Boidin et al., 1998; Feibelman et al., 1997; Parmasto, 1995; Stalpers, 1993). According to standard practice we also listed *Aporpium caryae* (Schwein.) Teixera & D.P. Rogers (family *Aporpiaceae*). Thus, the orders *Stereales, Poriales, Cantharellales* and *Hymenochaetales* comprise Karelia’s most common aphyllophoroid fungi. Two of these orders account for practically all *Corticiaceae* while *Poriaceae* make up about 70% of all species. The aphyllophoroid fungus biota of Karelia is dominated by the families *Poriaceae* (103 species), *Hyphodermataceae* (36 species), *Hymenochaetaceae* (31 species) and *Meruliaceae* (29 species). Each family contains an average of 9.2 species and 3.4 genera while each genus in turn contains an average of 2.7 species. The largest genera are *Phellinus* s. lato (19 species), *Antrodia* s. lato (15), *Hyphodontia* s. lato (14), *Oligoporus* s. lato (13), *Skeletocutis* s. lato (12), *Polyporus* s. lato (10), *Peniophora* s. lato (9) and *Ramaria* s. lato (9). A large number of species in such typical boreal genera as *Antrodia, Oligoporus* and *Skeletocutis* indicates that Karelian mycobiota is boreal in character.

Table 21

Taxonomy of the aphyllophoroid fungi recorded in Russian Karelia

Orders and families (number of genera/species)	Genera (number of species)
BOLETALES (4/12)	
Coniophoraceae (4/12)	*Coniophora* (4), *Leucogyrophana* (5), *Pseudomerulius* (1), *Serpula* (2)
CANTHARELLALES (14/39)	
Albatrellaceae (1/3)	*Albatrellus* (3)
Cantharellaceae (2/3)	*Cantharellus* (2), *Craterellus* (1)
Clavariaceae (3/9)	*Clavaria* (4), *Clavulinopsis* (4), *Ramariopsis* (1)
Clavariadelphaceae (1/6)	*Clavariadelphus* (6)
Clavulinaceae (1/2)	*Clavulina* (2)
Gomphaceae (1/1)	*Gomphus* (1)
Hydnaceae (1/2)	*Hydnum* (2)
Lentariaceae (1/2)	*Lentaria* (2)
Ramariaceae (1/9)	*Ramaria* (9)
Sparassidaceae (1/1)	*Sparassis* (1)
Typhulaceae (1/1)	*Pistillaria* (1)
GANODERMATALES (1/2)	
Ganodermataceae (1/2)	*Ganoderma* (2)
HERICIALES (9/14)	
Auriscalpiaceae (2/2)	*Auriscalpium* (1), *Gloiodon* (1)
Clavicoronaceae (1/1)	*Clavicorona* (1)
Gloeocystidiellaceae (3/8)	*Conferticium* (2), *Gloeocystidiellum* (5), *Laxitextum* (1)
Hericiaceae (3/3)	*Creolophus* (1), *Dentipellis* (1), *Hericium* (1)
HYMENOCHAETALES (7/32)	
Asterostromataceae (1/1)	*Asterodon* (1)
Hymenochaetaceae (6/31)	*Coltricia* (1), *Hymenochaete* (3), *Inonotus* (4), *Onnia* (3), *Phellinus* (19), *Phylloporia* (1)
LACHNOCLADIALES (3/5)	
Dichostereaceae (1/1)	*Dichostereum* (1)
Lachnocladiaceae (2/4)	*Scytinostroma* (3), *Vararia* (1)
PORIALES (43/124)	
Climacodontaceae (1/1)	*Climacodon* (1)
Poriaceae (33/103)	*Amylocystis* (1), *Anomoporia* (1), *Antrodia* (15), *Antrodiella* (5), *Bjerkandera* (2), *Ceriporiopsis* (4), *Cerrena* (1), *Climacocystis* (1), *Coriolopsis* (1), *Daedaleopsis* (3), *Datronia* (2), *Diplomitoporus* (3), *Fibuloporia* (1), *Fomes* (1), *Fomitopsis* (2), *Gloeophyllum* (5), *Hapalopilus* (2), *Haploporus* (1), *Heterobasidion* (2), *Ischnoderma* (2), *Laetiporus* (1), *Lenzites* (1), *Leptoporus* (1), *Oligoporus* (14), *Perenniporia* (1), *Piloporia* (1), *Pycnoporus* (1), *Skeletocutis* (12), *Spongipellis* (1), *Trametes* (6), *Trichaptum* (4), *Tyromyces* (3)
Phaeolaceae (2/2)	*Phaeolus* (1), *Pycnoporellus* (1)
Polyporaceae (3/12)	*Dichomitus* (1), *Piptoporus* (1), *Polyporus* (10)
Rigidoporaceae (4/6)	*Ceriporia* (2), *Oxyporus* (2), *Physisporinus* (1), *Rigidoporus* (1)
SHIZOPHYLLALES (3/3)	
Schizophyllaceae (2/2)	*Henningsomyces* (1), *Schizophyllum* (1)
Stromatoscyphaceae (1/1)	*Stromatoscypha* (1)
STEREALES (58/148)	
Amylocorticiaceae (3/3)	*Amylocorticium* (1), *Irpicodon* (1), *Plicatura* (1)
Atheliaceae (7/19)	*Athelia* (5), *Byssocorticium* (2), *Ceraceomyces* (5), *Fibulomyces* (2), *Leptosporomyces* (1), *Piloderma* (2), *Tylospora* (2)
Botryobasidiaceae (2/7)	*Botryobasidium* (6), *Botryohypochnus* (1)
Corticiaceae s. str . (4/5)	*Corticium* (2), *Cytidia* (1), *Punctularia* (1), *Vuilleminia* (1)
Hyphodermataceae (13/36)	*Amphinema* (1), *Basidioradulum* (1), *Bulbillomyces* (1), *Crustoderma* (1), *Cylindrobasidium* (1), *Hyphoderma* (6), *Hyphodontia* (14), *Hypochnicium* (5), *Intextomyces* (1), *Odonticium* (1), *Radulomyces* (1), *Schizopora* (2), *Subulicystidium* (1)
Meruliaceae (11/29)	*Byssomerulius* (2), *Chondrostereum* (1), *Dacryobolus* (2), *Gloeoporus* (2), *Merulius* (1), *Mycoacia* (2), *Phanerochaete* (6), *Phlebia* (8), *Phlebiopsis* (1), *Resinicium* (2), *Scopuloides* (1)
Peniophoraceae (1/9)	*Peniophora* (9)
Podoscyphaceae (1/1)	*Stereopsis* (1)
Sistotremataceae (3/10)	*Sistotrema* (4), *Sistotremastrum* (2), *Trechispora* (4)
Steccherinaceae (4/8)	*Cystostereum* (1), *Irpex* (1), *Junghuhnia* (4), *Steccherinum* (2)
Stereaceae (5/10)	*Amylostereum* (2), *Chaetoderma* (1), *Columnocystis* (1), *Laurilia* (1), *Stereum* (5)
Tubulicrinaceae (1/7)	*Tubulicrinis* (7)
Xenasmataceae (1/4)	*Phlebiella* (4)
THELEPHORALES (9/27)	
Bankeraceae (5/16)	*Bankera* (1), *Boletopsis* (2), *Hydnellum* (6), *Phellodon* (4), *Sarcodon* (3)
Thelephoraceae (4/11)	*Pseudotomentella* (1), *Thelephora* (1), *Tomentella* (8), *Tomentellopsis* (1)
TREMELLALES (1/1)	
Aporpiaceae (1/1)	*Aporpium* (1)
11 orders, 44 families	150 genera (404 species)

The substrate is the single largest factor determining the presence and succession of a group of macromycetes within a given biogeocenosis. About 85% of all aphyllophoroid macromycetes known in Karelia are wood-inhabiting (xylotrophic) fungi. Their substrate is consists of living, dead standing or windfallen trunks, branches and stumps of various woody species. The most common pathogenic macromycetes attacking living trees are *Heterobasidion annosum* (Fr.) Bref. s. lato*, Inonotus obliquus* (Pers.: Fr.) Pilat*, Onnia leporina* (Fr.) H. Jahn*, Phaeolus schweinitzii* (Fr.) Pat.*, Phellinus chrysoloma* (Fr.) Donk*, Ph. pini* (Brot.: Fr.) A. Ames and *Ph. tremulae* (Bondartsev) Bondartsev & Borisov. Most aphyllophoroid fungi are classified as saprotrophic; in other words, the destruction of dead wood is their main ecological function in forest ecosystems. They play a leading role in practically all stages of the biological decomposition of dead wood. Only some saprophytes such as *Fomitopsis pinicola* (Sw.: Fr.) P. Karst. and *Ganoderma lipsiense* (Batsch) G.F. Atk. are also capable of colonising weakened living trees. Most aphyllophoroid macromycetes prefer a broad range of coniferous or deciduous trees while species concentrating on a narrow range are relatively scarce as too are omnivorous species. Fifteen per cent of 357 wood-decomposing species are omnivorous, i.e. they can grow on both deciduous and coniferous trees. 131 are restricted solely to conifers and 154 species to deciduous hosts. Species related to major forest forming trees are most prolific. Thus, for example, 121 species were found on pine, 123 on spruce, 123 on aspen, 109 on birch and 67 on alder. A certain preference pattern is exhibited by a few species such as *Antrodia infirma* Renvall & Niemelä*, A. primaeva* Renvall & Niemelä*, Diplomitoporus flavescens* (Bres.) Ryvarden*, Oligoporus lateritius* (Renvall) Ryvarden & Gilb.*, Peniophora pini* (Schleich.: Fr.) Boidin*, Phellinus pini* (only grow on pine), *Onnia leporina* (on spruce), *Antrodia pulvinascens* (Pilát) Niemelä*, Peniophora polygonia* (Pers.: Fr.) Bourdot et Galzin*, Phellinus tremulae, Polyporus pseudobetulinus* (Pilát) Thorn, Kotir. & Niemelä (on aspen), *Lenzites betulina* (L.: Fr.) Fr.*, Piptoporus betulinus* (Bull.: Fr.) P. Karst. (on birch), and *Cytidia salicina* (Fr.) Burt (on willow). About 14% of Karelia's aphyllophoroid fungus species grow on the ground. This group is dominated by *Cantharellaceae* and includes *Albatrellus, Cantharellus* and *Craterellus*, and *Clavariaceae*, species of the family *Bankeraceae* being less common.

Wood-inhabiting aphyllophoroid macromycetes may be used to assess the impact of human activities on forest ecosystems (Scientific basis …, 1992). Their species composition in such forests is markedly impoverished, sensitive species being replaced by the widespread eurytropic macromycetes. Highest species diversity is typically found in old natural forest phytocenoses which are slightly affected by human activities and where large quantities of dead wood provide a substrate for fungi (Bondartseva et al., 1994). In North Europe aphyllophoroid species dominated by shelf fungi (*Polyporaceae* s. l) are widely used as indicators of old natural forests requiring protection. As Russian Karelia and Finland have similar climates and flora we have used the indicator scale proposed by Finnish mycologists (Kotiranta & Niemelä, 1996) in which each selected species has its own "indicator value" (• = a value of 1 or •• = a value of 2). In all, fifty aphyllophoroid fungus species found in Karelia have been ascribed indicator status (Table 22). Some of these, e. g. *Amylocystis lapponica* (Romell) Singer*, Diplomitoporus crustulinus* (Bres.) Domański and *Phellinus nigrolimitatus* (Romell) Bourdot & Galzin, are considered to be relicts (Bondartsev, 1953; Parmasto, 1959).

Some aphyllophoroid fungi known in Karelia exhibit irregular distribution patterns. Many species found sporadically or represented by a single find are classified as rare. The location of rare and indicator species is shown in Table 22. These are the ones most susceptible to environmental changes and require a specific protection management programme.

The Red Data Book of Karelia (1995) lists 23 fungus species including five aphyllophoroid species, namely *Clavariadelphus pistillaris* (L.: Fr.) Donk*, Cantharellus tubaeformis* (Bull.: Fr.) Fr.*, Craterellus cornucopioides* (L.: Fr.) Pers.*, Hericium coralloides* (Scop.: Fr.) Pers. and *Hydnum repandum* L.: Fr.. One species, *Polyporus pseudobetulinus* is listed in the Red Data Book of East Fennoscandia (Kotiranta et al., 1998). Based on a distribution analysis of macromycetes nine more species, i.e. *Anomoporia bombycina* (Fr.) Pouzar, *Antrodia pulvinascens*, *Aporpium caryae*, *Dentipellis fragilis* (Pers.: Fr.) Donk, *Dichomitus squalens* (P. Karst.) D. A. Reid, *Ganoderma lucidum* (M. A. Curtis: Fr.) P. Karst., *Polyporus pseudobetulinus* – category 3 (rare) – and *Punctularia strigosozonata* (Schwein.) P.H.B. Talbot and *Tyromyces fissilis* (Berk. & M.A. Curtis) Donk – category 4 (indeterminate) – have been recommended for protection in Karelia. A proposal was made to remove one species, *Hericium coralloides* from the list of protected species to be published in the next edition of the Red Data Book of Karelia as this is fairly common in habitats affected by human activities and other environments.

One of the main ways of protecting rare fungus species is to establish protected areas by prohibiting commercial activities in forests with undisturbed ecosystems. Such areas are established in order to preserve the gene pool of living organisms and are used as model natural ecosystems in which ecological and biological monitoring can be conducted (Belousova, 1992). In order to develop protection programmes and to present convincing ecological arguments in favour of the establishment of protected areas it is necessary to assess the biological diversity of individual groups of organisms and the extent of their restriction to certain biogeocenological environments as well as to identify rare species and their habitats.

An inventory was undertaken of all aphyllophoroid fungi identified in nature reserves, national parks and other strictly protected areas (Table 22). The largest number of aphyllophoroid macromycetes was reported from the **Kivach Strict Nature Reserve** which is typical in character of the Karelian mid-taiga subzone. Altogether 272 aphyllophoroid fungus species are known in the reserve (Freindling, 1949; Rodionova, 1973; Salo, 1986; Bondartseva & Svishch, 1993; Bondartseva et al., 1996; Lositskaya et al., 2001; and others). Twenty-eight species out of these 272 are indicators and yield a total indicator value of 34 (indicating well preserved forests). It should also be noted that the Kivach

Table 22

Rare and indicator species of aphyllophoroid fungi in the Republic of Karelia

Species	Substrate	Biogeographical provinces												
		Ks	Kk+ Kpor	Kpoc			Kon			Kton	Kb	Kl		Kol
		a	b	c	d	e	f	g	h	i	j	k	l	m
Amylocorticium subincarnatum (Peck) Pouzar	S							+						
••*Amylocystis lapponica* (Romell) Singer	S	+	+	+	+		+	+		+			+	+
•*Anomoporia bombycina* (Fr.) Pouzar	conif			+	+									
•• *Antrodia albobrunnea* (Romell) Ryvarden	conif			+	+					+				
••*A. crassa* (P. Karst.) Ryvarden	conif				+					+				
••*A. infirma* Renvall & Niemelä	conif				+					+				
A. mellita Niemelä & Penttilä	As							+		+				
••*A. primaeva* Renvall & Niemelä	P			+						+				
•*A. pulvinascens* (Pilát) Niemelä	As									+			+	
••*Antrodiella citrinella* Niemelä & Ryvarden	S			+	+					+				
Aporpium caryae (Schwein.) Teixera & D.P. Rogers	B				+					+			+	
•*Asterodon ferruginosus* Pat.	As, B, P, S	+		+	+		+	+			+			+
Byssocorticium atrovirens (Fr.) Bondartsev & Singer	B							+						
Byssomerulius rubicundus (Litsch.) Parmasto	P, S	+												
**Cantharellus tubaeformis* Bull.: Fr.	soil							+			+		+	+
Ceraceomyces violascens (Fr. : Fr) Jülich	P			+										
•*Chaetoderma luna* (Romell ex Rogers & H. S. Jacks.) Parmasto	P, S	+		+		+		+					+	
***Clavariadelphus pistillaris* (L.: Fr.) Donk	litter				+			+						
**Craterellus cornucopioides* (L.: Fr.) Pers.	soil							+						
•*Crustoderma dryinum* (Berk. & M.A. Curtis) Parmasto	S	+					+	+			+			
••*Cystostereum murraii* (Berk & M.A. Curtis) Pouzar	S	+												
Dentipellis fragilis (Pers.: Fr.) Donk	As				+			+					+	
••*Dichomitus squalens* (P. Karst.) D.A. Reid	P	+			+	+		+						
••*Diplomitoporus crustulinus* (Bres.) Domański	S	+		+	+					+				
D. lindbladii (Berk.) Gilb. & Ryvarden	P, S				+			+					+	
•*Fomitopsis rosea* (Alb. & Schwein.: Fr.) P. Karst.	S	+	+	+	+		+ (#)	+	+	+			+	+
Ganoderma lucidum (M.A. Curtis : Fr.) P. Karst.	Larix												+	
••*Gloeophyllum protractum* (Fr.) Imaz.	P		+	+	+		(#)	+		+				
•*Gloeoporus taxicola* (Pers.: Fr.) Gilb. & Ryvarden	P, S	+		+	+		+	+		+				
•*Gloiodon strigosus* (Schwein.: Fr.) P. Karst.	As			+	+			+						
Gomphus clavatus (Pers.: Fr.) Gray	soil													
Haploporus odorus (Sommerf.: Fr.) Bondartsev & Singer	Sal	+			+			+						(+)
***Hericium coralloides* (Scop.: Fr.) Pers.	Al, As, B	+			+	+	(+)	+		+	+		+	+
•*Irpicodon pendulus* (Fr.) Pouzar	conif							+						
••*Junghuhnia collabens* (Fr.) Ryvarden	S				+		+	+	+	+			+	
•*J. luteoalba* (P. Karst.) Ryvarden	P, S	+		+	+			+		+	+			+
J. separabilima (Pouzar) Ryvarden	As							+						
••*Laurilia sulcata* (Burt) Pouzar	S	+												
•*Leptoporus mollis* (Pers.: Fr.) Pilát	P, S	+		+	+		(#)	+		+			+	
Mycoacia aurea (Fr.) J. Erikss. & Ryvarden	As			+				+						
•*Odonticium romellii* (S. Lundell) Parmasto	P	+					+							
•*Oligoporus guttulatus* (Peck) Gilb. & Ryvarden	S							+		+				
••*O. hibernicus* (Berk. & Broome) Gilb. & Ryvarden	P, S			+	+									
•*O. lateritius* (Renvall) Ryvarden & Gilb.	P			+	+					+				
•*O. leucomallellus* (Murrill) Gilb. & Ryvarden	S			+	+		+				+			
•*O. placentus* (Fr.) Gilb. & Ryvarden	P			+	+	+				+				
•*O. sericeomollis* (Romell) Bondartseva	P, S			+	+			+		+				
•*Onnia leporina* (Fr.) H. Jahn	S	+			+			+		+			+	
Peniophora septentrionalis Laurila	S	+												
•*Perenniporia subacida* (Peck) Donk	As, S	+		+	+		+		+	+			+	
•*Phaeolus schweinitzii* (Fr.) Pat.	Larix, P						+ (#)			+			+	
•*Phellinus chrysoloma* (Fr.) Donk	P, S	+	+	+	+			+	+	+	+		+	
•*Ph. ferrugineofuscus* (P. Karst.) Bourdot	P, S	+	+	+	+	+	+	+	+	+	+		+	
•*Ph. lundellii* Niemelä	Al, B	+		+	+	+		+	+	+	+	+	+	+
•*Ph. nigrolimitatus* (Romell) Bourdot & Galzin	S	+		+	+		+	+		+	+			
•*Ph. pini* (Brot.: Fr.) A. Ames	P	+	+	+	+	+		+		+	+	+	+	
•*Ph. viticola* (Schwein.: Fr.) Donk	P, S	+		+	+	+	+	+		+	+			+
•• *Phlebia centrifuga* P. Karst.	P, S	+			+			+	+				+	
••*Ph. cornea* (Bourdot & Galzin) J. Erikss.	P			+										
•*Ph. cretacea* (Bourdot & Galzin) J. Erikss. & Hjortstam	P, S	+		+		+		+						
•*Ph. serialis* (Fr.) Donk	S						(+)							+
Piloporia sajanensis (Parmasto) Niemelä	conif			+										
****Polyporus pseudobetulinus* (Pilát) Thorn, Kotir. & Niemelä	As	+			+					+				
P. tubaeformis (P.Karst.) Ryvarden & Gilb.	As	+												
***P. umbellatus* Fr.	soil							+						

End. table 22

Species	Substrate	Biogeographical provinces												
		Ks	Kk+ Kpor	Kpoc			Kon			Kton	Kb	Kl		Kol
		a	b	c	d	e	f	g	h	i	j	k	l	m
•*Pseudomerulius aureus* (Fr.: Fr.) Jülich	P			+								+		
Punctularia strigosozonata (Schwein.) Talbot	As							+						
•*Pycnoporellus fulgens* (Fr.) Donk	S						(#)	+	+	+		+	+	
Rigidoporus crocatus (Pat.) Ryvarden	As, B, S							+	+	+				
Sistotrema confluens Pers.: Fr.	soil							+						
• *Sistotremastrum suecicum* Litsch. ex J. Erikss.	P	+		+	+	+	+	+		+				+
••*Skeletocutis jelicii* Tortić & A. David	conif				+									
••*S. lenis* (P. Karst.) Niemelä	As, P	+		+	+		+	+		+		+		
•*S. odora* (Sacc.) Ginns	As, S	+		+	+			+		+				
••*S. stellae* (Pilát) Jean Keller	conif				+					+				
•***Sparassis crispa* (Wulfen : Fr.) Fr.	soil												+	
Spongipellis spumeus (Sowerby : Fr.) Pat.	As							+						
••*Tyromyces canadensis* Overh. ex J. Lowe	wood				+									
T. fissilis (Berk. & M.A. Curtis) Donk	B							+						

Note. Floristic provinces: Ks = Kuusamo; Kk = Karelia keretina; Kpor = Karelia pomorica orientalis; Kpoc = Karelia pomorica occidentalis; Kon = Karelia onegensis; Kton = Karelia transonegensis; Kb = Karelia borealis; Kl = Karelia ladogensis; Kol = Karelia olonetsensis.

Symbols used for localities: a = Paanajärvi National Park; b = White Sea islands; c = Kostomuksha Reserve; d = Kalevala National Park; e = Lake Maslozero area, Medvezhyegorsk district; (+) = Lake Segozero (Lebedeva, 1933) and Lake Rugozero (H) areas; f = based on herbaria and literature; Vichka Station and Krivijärvi Station areas (H), (+) = Marsian Waters, Lake Sandal area, Hyrsyla area (LE), (#) = Semchezero and Lake Porosozero areas (H); g = Kivach Reserve; h = Kizhi Archipelago; i = Vodlozero National Park; j = Tolvajärvi Forest Estate, (+) = Suojärvi area; k = northern Priladozhye; l = Valaam Archipelago; m = Matrosy Forest Estate, (+) = Petrozavodsk area, Pedaselga, Ilyinskoye (LE).

Symbols preceding the name of species: •= indicator species for old and •• = very old forests (Kotiranta & Niemela, 1996); * = species listed in the Red Data Book of Karelia (1995); ** = species listed in the Red Data Book of RSFSR (1988); *** = species listed in the Red Data Book of East Fennoscandia (Kotiranta et al., 1998).

Symbols used for the substrates on which species were collected: Ac = *Acer* spp.; Al = *Alnus* spp.; As = *Populus tremula*; B = *Betula* spp.; Junip = *Juniperus communis*; fungi = on old basidiomata of macromycetes; L = *Larix* spp.; P = *Pinus sylvestris*; S = *Picea* spp.; Pad = *Padus racemosa*; Sor = *Sorbus aucuparia*; Ul = *Ulmus* spp.; Q = *Quercus robur*; Sal = *Salix* spp.; conif = on coniferous trees; litte = on the litter; soil = on the soil.

Reserve is the only habitat in Karelia for 35 macromycete species including the rare and interesting macromycetes *Amylocorticium subincarnatum* (Peck) Pouzar, *Byssocorticum atrovirens* (Fr.) Bondartsev & Singer, *Junghuhnia separabilima* (Pouzar) Ryvarden, *Oligoporus undosus* (Peck) Gilb. & Ryvarden, *Punctularia strigosozonata, Sistotrema confluens* Pers.: Fr., and *Tyromyces fissilis*.

Incorporating the Kizhi Reserve Museum, the **Kizhi Skerries Reserve** consists of a number of islands affected to varying degrees by human activities. It contains 66 aphyllophoroid fungus species (Bondartseva et al., 1997, 1999; Kozlov et al., 1999). The number of species is much higher on B. Klimenetsky Island than on Kizhi Island because the former is larger and its natural ecosystems are far better preserved as is evidenced by the presence of the indicator and rare species *Junghuhnia collabens* (Fr.) Ryvarden, *Phellinus ferrugineofuscus* (P. Karst.) Bourdot & Galzin, *Phlebia centrifuga* P. Karst., *Pycnoporellus fulgens* (Fr.) Donk, *Rigidoporus crocatus* (Pat.) Ryvarden and *Trichaptum biforme* (Fr.) Ryvarden.

The **Valaam Archipelago Nature Park** lies in the northern part of Lake Onega and contains a unique combination of natural factors and ecosystems. Its climate favours the evolution of a nemoral biota complex containing numerous species known only to southern Karelia. The Valaam Archipelago is populated by 116 fungus species from the group studied (Ecosystems of Valaam …, 1989; Lositskaya, 1997) including 17 indicator species. Of the greatest interest are *Antrodia pulvinascens, Aporpium caryae, Ceriporia viridans* (Berk. & Broome) Donk, *Cantharellus tubaeformis, Creolophus cirrhatus* (Pers.: Fr.) P. Karst., *Dentipellis fragilis, Diplomitoporus lindbladii* (Berk.) Gilb. & Ryvarden and *Perenniporia subacida* (Peck) Donk. This is the only habitat in Karelia of the rare species *Ganoderma lucidum* and *Sparassis crispa* (Wulfen : Fr.) Fr.

The **Vodlozero National Park** is located in eastern Karelia and extends partly into the Archangelsk Region. The park lies in the north and mid-taiga subzones, the larger part of its area consisting of mid-taiga green-moss coniferous forests. It has not previously been mycologically studied. Together with Finnish data our results (Penttilä oral presentation) indicate that the park is presently inhabited by 88 aphyllophorales species (mostly polypores). Of these 31 are indicator species which yield a total indicator value of 40 and thus indicate the well preserved nature of its forest ecosystems. The park contains one habitat of *Polyporus pseudobetulinus* which is listed in the Red Data Book of East Fennoscandia (Kotiranta et al., 1998).

Established in order to preserve a fragment of typical north taiga in European Russia, the **Kostomuksha Strict Nature Reserve** is dominated by old growth pine forests. It hosts 153 macromycete species (Lindgren, 1996; Krutov et al., 1998; Lositskaya et al., 1999). The thirty-two indicator species identified had a total indicator value a total of

41 and thus confirmed the high conservation value of the forests of the reserve. The most interesting of the rare species found here are *Anomoporia bombycina* (Fr.) Pouzar, *Antrodia primaeva, Antrodiella citrinella* Niemelä & Ryvarden, *Byssocorticium molliculum* (Bourdot) Jülich and *Gloiodon strigosus* (Schwein.: Fr.) P. Karst.

Soon to be established, the **Kalevala National Park** also lies in the north-taiga subzone of Karelia and is dominated by primeval forest communities. It is home to 108 aphyllophoroid fungi (Lindgren, 1997b; Krutov et al., 1998) including 36 indicator species. The park is superior with respect to the total indicator value of its indicator species (51) to all other strictly protected nature areas in Karelia and therefore ranks as a unique massif which should be preserved intact. The occurrence of the rare species *Dentipellis fragilis, Diplomitoporus flavescens, D. lindbladii* and *Polyporus pseudobetulinus* together with Karelia's only finds of *Piloporia sajanensis* (Parmasto) Niemelä and *Tyromyces canadensis* Overh. ex J. Lowe provides a convincing argument in favour of the protection of this territory.

Another unique area in Karelia is the **Paanajärvi National Park**. This north-taiga region of Fennoscandia with extensive tracts of more or less virgin spruce forest has been virtually unaffected by human activities and its ecosystems have retained almost all of their intrinsic features. The park is characterised by low hills. The Finnish mycologist M. Laurila (Laurila, 1939) was the first to collect aphyllophoroid fungi here before the Second World War. The park is populated by 131 aphyllophoroid fungus species (Lositskaya, 2000) and provides the only habitats known in Karelia for *Byssomerulius rubicundus* (Litsch.) Parmasto, *Cystostereum murraii* (Berk. & M.A. Curtis) Pouzar, *Intextomyces contiguus* (P. Karst.) J. Erikss. & Ryvarden, *Peniophora septentrionalis* Laurila and *Polyporus tubaeformis* (P. Karst.) Ryvarden & Gilb. So far 26 indicator species have been identified.

The **Tolvajärvi Landscape Reserve** has a population of 122 aphyllophoroid fungus species, ten species acting as indicators. The finds of some species including *Amylostereum laevigatum* (Fr.) Boidin, *Athelia acrospora* Julich, *A. neuhoffii* (Bres.) Donk, *Ceraceomyces tessulatus* (Cooke) Jülich, *Gloeocystidiellum citrinum* (Pers.) Donk, *Lentaria afflata* (Lagget) Corner, *Radulomyces confluens* (Fr.) M. P. Christ, *Tomentella ferruginea* (Pers.: Fr.) Pat. and *Tylospora fibrillosa* (Burt) Donk, were the first for these species in the whole of Karelia.

To sum up our inventory has revealed a great number of rare and indicator species in strictly protected nature areas. Fungi absent from other forest cenoses were found in each area, thus providing a further argument for their protection. Unfortunately the biodiversity of aphyllophoroid macromycetes is as yet well understood only in the Kivach Reserve. Other strictly protected areas need also to be thoroughly studied in order to make more complete the lists of their aphyllophoroid fungus species.

The depth of study of aphyllophoroid fungi varies from one floristic province to another. We understand floristic provinces as biogeographic provinces distinguished by Finnish naturalists on the basis of botanical criteria and widely used up until the present day (Mela, 1906; Heikinheimo & Raatikainen, 1971; Kravchenko et al., 2000). With slight changes to their boundaries these provinces provided the basis for the floristic demarcation of Karelia proposed by Ramenskaya (1983). The Zaonezhye floristic province (*Kon – Karelia onegensis*) is the best studied. Our evidence along with relevant literature and herbaria (LE, H, PZV) indicates that it is inhabited by 297 aphyllophoroid fungus species. Other floristic provinces in the mid-taiga subzone contain much smaller numbers of macromycetes of this group: 123 species in the Suojärvi province (*Kb – Karelia borealis*), 88 species in the Vodlozero province (*Kton – Karelia transonegensis*), 144 species in the Priladozhye province (*Kl – Karelia ladogensis*) and 109 species in the Olonets province (*Kol – Karelia olonetsensis*). The best studied floristic province in the north-taiga subzone is the Kem province (*Kpoc – Karelia pomorica occidentalis*) in which 209 aphyllophoroid macromycete species have been recorded. The Northwestern hill (Imandra) province (*Ks – Kuusamo*) has 131 species. Little is known about the fungi of the Topozero (*Kk – Karelia keretina*) and Vygozero (*Kpor – Karelia pomorica orientalis*) provinces: only 33 species have been found on some White Sea islands (Krutov & Lositskaya, 1999). Moreover, the Pudozh floristic province (*Kp* – outside East Fennoscandia) has not yet been studied at all.

Conclusion. As the degree of study of aphyllophoroid fungi in Karelia varies from one area to another a comprehensive floristic analysis is not yet feasible. Our inventory of the species composition of this group of fungi in protected areas has revealed many rare, disappearing and indicator species but this work is not yet over. It needs to be continued in carefully selected forests from different floristic provinces in order to throw more light on the distribution pattern of aphyllophoroid fungi in Karelia and to provide data for forecasting the dynamics of forest ecosystems varying in age and condition.

3.4 Lichens

Introduction. Lichens are an integral part of most terrestrial ecosystems. They form large biomasses which contribute significantly to the processes of metabolism and energy exchange occurring in taiga biogeocenoses and together with other components provide a stable basis for their functioning.

The first lichenological studies in Karelia were carried out about 150 years ago by amongst others the pioneering Finnish botanist W. Nylander. In 1850 Nylander reported his first lichenological findings from field trips to northern shores of Lake Ladoga and surrounding areas of Petrozavodsk. (Nylander, 1852a, 1852b, 1866).

Karelian lichens have also been studied by numerous other Finns such as J. P. Norrlin, E. A. Vainio, V. Räsänen and A. V. Auer as well as the Swedish lichenologist S. Ahlner. As a result of this work we have now a considerable body of knowledge concerning the lichens of Ladoga, Olonets and Onega Karelia as well as the Lake Paanajärvi area (Fadeeva et al., 1997, Fadeeva & Golubkova, 1998).

In the early 20th century Russian botanists also studied lichens in Olonets and Onega Karelia although only a small part of their results, mostly those of V. P. Savicz (1912, 1950, Olonets scientific..., 1921, Gollerbach, 1930), has been published.

By the mid-1990s, Russian and foreign authors had published over 120 papers concerning the distribution of lichens in what is now the Republic of Karelia. Their data, together with the collections of the Botanical Institute, RAS, St. Petersburg (LE), the Petrozavodsk State University (PZV), the Forest Research Institute, Karelian Research Centre, RAS (PTZ), and the Botanical Museum, Finnish Museum of Natural History, Helsinki (H), are summarised in a preliminary list of Karelian lichens and lichenicolous fungi (Fadeeva et al., 1997) which consists of 974 specific and intraspecific lichen taxa and 39 lichenicolous fungus species. The taxa (species, subspecies and varieties) of the biogeographic provinces of East Fennoscandia which lie within the Karelian Republic (Mela & Cajander, 1906, Heikinheimo & Raatikainen, 1971) are distributed as follows (Fig. 41): *Karelia ladogensis (Kl):* 803 taxa (79.3% of total), *Karelia olonetsensis (Kol)*: 144 (14.2%), *Karelia onegensis* (*Kon*): 511 (50.4%), *Karelia transonegensis (Kton*): 157 (15.5%), *Karelia borealis* (*Kb*): 119 (11.8%), *Karelia pomorica orientalis* (*Kpor*): 31 (3.1%), *Karelia pomorica occidentalis* (*Kpoc*): 247 (24.4%), *Regio kuusamoensis (Ks):* 486 (48.0%), and *Karelia keretina* (*Kk*): 205 (20.3%).

Analysis of the distribution of taxa indicates that very little is known about the areas of northeastern and Central Karelia between the Finnish border and the White Sea coast.

We know practically nothing about the vast and interesting territory east of Lake Onega, especially its southeastern margin which is located on the Russian Plain outside the Fennoscandian Shield and is regarded as a separate province in its own right, i.e. *Karelia pudogensis*, *Kp* (Kravchenko et al., 2000).

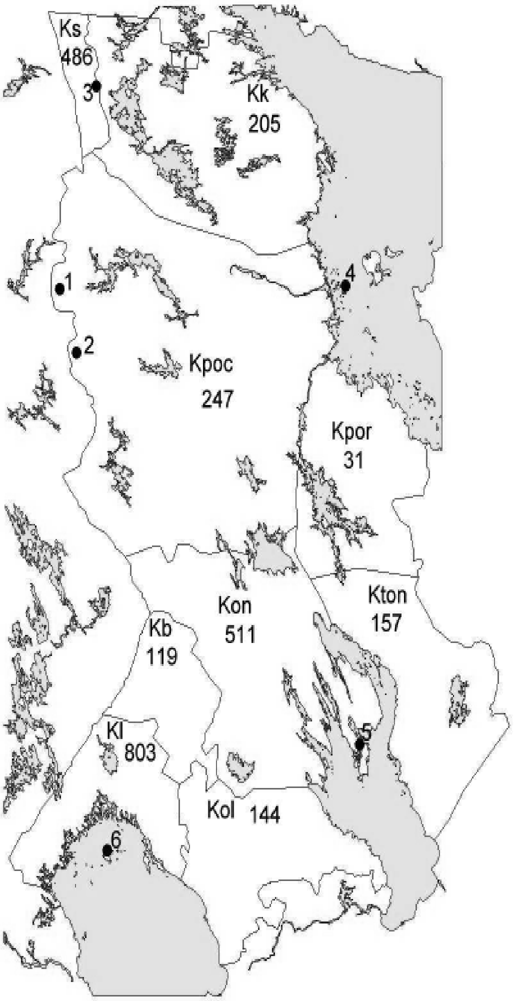

Fig. 41. Numbers of species and intraspecific taxa of lichens and lichenicolous fungi in the biogeographic provinces of Karelia

• lichen flora studied

1 – proposed Kalevala National Park; 2 – Kostomuksha Strict Nature Reserve; 3 – Paanajärvi National Park; 4 – Kuzov Reserve; 5 – Kizhi Reserve; 6 – Valaam Archipelago Nature Park

Over the past few years lichenological studies have been pursued more actively in Karelia and lichens recorded for the first time in the biogeographic provinces of Karelia are being found every field season (Inventory and study, 1998; Results of inventory, 1998, Inventory and study, 2000; Kravchenko et al., 2000, Tarasova, 2001). The Keret Archipelago located in the White Sea in the northeasternmost part of Karelia contains 356 lichen taxa (Himelbrant et al., 2000, 2001), 41 of which are additions to the checklist by Fadeeva et al. (1997). The Kivach Strict Reserve has 317 lichen species, 54 being reported from Karelia for the first time (Hermansson et al., 2000). As the authors of the above papers have not yet published complete lists of species, some species are not covered in our analysis of lichen flora.

A retrospective study of the northern shores and islands of Lake Ladoga including the area of the proposed Ladoga Skerries National Park has provided a large body of new information on the occurrence of endangered lichen species in Karelia and East Fennoscandia. Two species previously unknown in Karelia were recently reported by Oksanen & Vitikainen (1999).

In preparing the latest editions of the Red Data Book of Karelia (1995) and the Red Data Book of East Fennoscandia (1998) the distribution of lichens in Karelia was analysed on the basis of available evidence and lists of species in need of protection were drawn up. Seventy-five lichen species have been assigned protected status and duly added to the Red Data Book of Karelia. Two further species, *Lobaria pulmonaria* (L.) Hoffm. and *Bryorià fremontii* (Tuck.) Brodo & D.Hawksw., are common to Karelia but have been assigned protective status at the Russian state level (Red Data Book of Russia, 1988). More recent field studies carried out in strict nature reserves and other parts of Karelia (Potasheva & Kravchenko, 1995; Fadeeva & Dubrovina, 1997; Results of inventory .., 1998; Inventory and study, 1998; Kravchenko, 2000) have shown that the above two species are not endangered in Karelia and that their prolificacy can be maintained in strictly protected areas (SPAs).

88 Karelian lichen species are listed in the Red Data Book of East Fennoscandia. The status of 85 of these species was assessed in accordance with the IUCN while the remaining three species were described as lichens to be protected in adjacent territories but not requiring protection in Karelia.

As lichens grow very slowly and are highly substrate-specific the only effective way to maintain their diversity is to protect their natural habitats. The main factors threatening rare species today are the logging of primeval forests and large-scale mining operations.

Lichens are highly sensitive to industrial pollution. The effect on lichens of air pollution from the Kostomuksha iron ore plant has been studied for a number of years (Potasheva (Fadeeva), 1993, 1995; Wainstein et al., 1994; Shapiro et al., 1994; Fadeeva, 1999). Results have shown that the metabolisms of lichen are disturbed even by low levels of pollution. Pollutants accumulate in the thallus of lichens causing populations of the more sensitive species to decline.

Undisturbed forest habitats form their own specific microclimates conducive to the growth of a variety of lichens. These are sometimes known as forest microclimate, a term proposed by Titov (1986). Species associated with such habitats are indicators of the age and integrity of a given stand of forest (Rose, 1976, Goward, 1994, Kuusinen et al., 1995, Kuusinen, 1996). Their presence in biotopes is used to identify biologically diverse fragments of primeval forest fragments requiring protection. 34 lichen species have been used to map old-growth forests in Finland (Kuusinen et al., 1995). A forest site containing ten or more indicator species is considered as warranting protection.

A study of forests growing along the Russian-Finnish border has shown that this above-mentioned Finnish procedure is applicable to the forests of Russian Karelia (Results of inventory .., 1998; Inventory and study.., 1998) or at least to those close to the border. However, lichenologists have since made some changes to the list of indicator species. For example, *Bryoria fremontii*, which occurs in Karelia in biotopes affected by human activities to differing degrees, is no longer considered an indicator species. According to Kravchenko (2000) it persists in slightly deforested areas and grows actively on tree stems in young pine stands. At the same time, *Icmadophila ericetorum* (L.) Zahlbr), which inhabits rotting logs in natural undisturbed and slightly disturbed forests, was added to the list of indicator species.

The diversity of lichens largely depends on the diversity of substrates and their accessibility to colonising lichens. In the opinion of the present author the existing and proposed strictly protected areas in Karelia (Belousova et al., 1992; Khokhlova et al., 2000) contain the complete (or almost complete) spectrum of Karelian environments. The main goal of lichenological studies in Karelia could be the identification and study of lichens in protected areas.

During the period 1997–2000 the author collected and identified a large number of lichen samples in the proposed Kalevala National Park (1997) and the Kizhi Reserve (1999–2000). The author's collections from the Kostomuksha Strict Reserve and the herbaria collected by other lichenologists and kept at the Forest Research Institute, KRC, RAS formed the material basis of this paper. Lichens collected by A.V. Kravchenko (Forest Research Institute, KRC, RAS) in 1994, 1998 and 2000 from the Kuzov Reserve and made available to the author were also studied.

Results of the inventory study of lichens undertaken in the proposed Kalevala National Park, in the Kizhi Reserve and in the Kuzov Reserve are summarised in Table 23. Species added to the annotated lists of lichens published earlier for other strictly protected areas are included in the present paper. Names of lichen taxa are given according to Santesson (1993) with some recent corrections by Vitikainen et al. (1997).

The **Kostomuksha Strict Nature Reserve** was established in order to protect typical northern taiga nature complexes. Pine stands which retain primeval forest characteristics prevail. 143 lichen species and subspecies have been reported in the reserve (Fadeeva & Dubrovina, 1997; Kravchenko et al., 2000). Four more species, i.e. *Cladina stygia* (Fr.) Ahti*, Peltigera lepidophora* (Nyl. ex Vain.) Bitter*, P. scabrosa* Th. Fr. and *Evernia divaricata* (L.) Ach. (coll.: M.Potasheva (Fadeeva), 1991, PTZ), were reported for the first time. It should be noted that the specimens referred to by Fadeeva & Dubrovina (1997) and again by Kravchenko et al. (2000) as *Cladonia coccifera* have since been re-identified as *C. borealis* S.Stenroos by Prof. T. Ahti of the University of Helsinki in 2000. Some species listed in the Red Data Book of Karelia, e.g. *Lobaria pulmonaria, Bryoria fremontii, Nephroma bellum* (Spreng.) Tuck. and *Ramalina dilacerata* (Hoffm.) Hoffm., are common in the reserve while two other species, *Stereocaulon dactylophyllum* Flörke and *Evernia divaricata*, were each found at just one locality. Also reported are the species *Dermatocarpon luridum* (With.) J.R.Laundon and *Evernia divaricata*, both listed in the Red Data Book of East Fennoscandia. The reserve is home to 21 indicator species including *Alectoria sarmentosa* (Ach.) Ach. subsp. *sarmentosa, Evernia mesomorpha* Nyl., *Leptogium saturninum* (Dicks.) Nyl., *Lobaria pulmonaria, Nephroma bellum, N. parile* (Ach.) Ach., *N. resupinatum* (L.) Ach., *Peltigera aphthosa* (L.) Willd., *P. canina* (L.) Willd., *P. leucophlebia* (Nyl.) Gyeln., and *P. praetextata* (Sommerf.) Zopf. This is clear evidence that the natural complexes of the reserve are well preserved.

At the same time chemical analysis of lichens (Fadeeva, 2001) has shown that the forests growing on the northern boundary of the reserve display slight but nevertheless clear effects of dust pollution from the Kostomuksha iron ore plant.

The proposed **Kalevala National Park** has attracted the attention of scientists as it hosts Fennoscandia's largest and Europe's westernmost massif of well-preserved pyrogenic primeval pine taiga (Results of inventory… 1998). Initial results of a lichen inventory conducted in the area have already been published and include data on material collected by T. Ahti in the Lake Sudnozero area during a botanical expedition to northern Karelia in 1996 (Fadeeva et al., 1997, Results of inventory…, 1998; Kravchenko et al., 2000). Taking into account recent evidence obtained mainly from the analysis of crustose species, the park has 139 lichen taxa (Table 23) of which two species are new to Karelia and 15 species new to the Kpoc province. 23 primeval forest indicator species are found in the park. Indeed, many indicator and rare species, e.g. *Lobaria pulmonaria, Bryoria fremontii, Nephroma bellum, Ramalina dilacerata, Leptogium saturninum, Nephroma parile, N. resupinatum, Pannaria pezizoides* (G.Weber) Trevis., *Parmeliella triptophylla* (Ach.) Müll.Arg., *Peltigera aphthosa, P. canina* and *P. praetextata,* are common in Kalevala. The park is the one of only two known locations in Karelia where *Arthonia incarnata* Th.Fr. ex Almq.[1] and *Cliostomum leprosum*[2] (Räsänen) Holien & Tønsberg have been found. It is essential that this important area be protected.

The **Paanajärvi National Park** remains more or less unaffected by human activities. Its comprises an unique combination of pine and spruce stands, fragments of mountain tundra and mountain forests, and large bedrock and limestone exposures. The lichen flora of the park has been thoroughly studied. The park contains 443 lichen species (Halonen, 1993). On studying the herbarium at the Forest Research Institute (PTZ) T. Ahti identified three more previous unknown species of *Cladonia: C. borealis* (colls.: A.Kravchenko, 1990, A. Kryshen, 1993), *C. macroceras* (Delise) Hav. (coll.: A. Kravchenko, 1990) and *C. metacorallifera* Asahina (coll. A. Kryshen, 1993). This was only the second identification of *C. metacorallifera* for the whole of Karelia; the species was first found in the area of the proposed Ladoga Skerries National Park (coll. A.Kravchenko, 1993,).

The abundance of rare and indicator species, many of which do not occur outside the park, makes this a highly valuable territory from the point of view of nature conservation. A number of rare lichen species such as *Alectoria sarmentosa* (Ach.) Ach. subsp. *vexillifera, Belonia russula* Nyl., *Brodoa intestiniformis* (Vill.) Goward*, Bryoria bicolor* (Ehrh.) Brodo & D.Hawksw., *Caloplaca decipiens* (Arnold) Blomb & Forssell*, Collema polycarpon* Hoffm., *Phaeophyscia kairamoi* (Vain.) Moberg*, Heterodermia speciosa* (Wulfen) Trevis., *Hypogymnia austerodes* (Nyl.) Räsäsnen*, Tholurna dissimilis* (Norman) Norman*, Omphalina hudsoniana* (H.S. Jenn.) H.E. Bigelow and *Synalissa symphorea* (Ach.) Nyl. either do not grow outside the park or occur only sporadically in Karelia. As our knowledge of their distribution is largely based on old collections further studies are needed. Thus, for example, *Omphalina hudsoniana, Lobaria scrobiculata* (Scop.) DC.*, Evernia divaricata* and *Ramalina thrausta* (Ach.) Nyl.*,* seem to be more common in Karelia than we had previously believed. At the same time our failure to find *Belonia russula* in its supposedly preferred habitat of Ladoga Karelia (Oksanen & Vitikainen, 1999) raises doubts as to its present existence. *Catillaria kivakkensis* (Vain.) Zahlbr. (Vainio, 1934) was reported at its favourite Mount Kivakka habitat but its systematic independence is now in doubt. The endangered species *Usnea longissima* Ach. known to occur at only two localities Karelia, one of which is close to Lake Paanajärvi, was found there in 1996 (Halonen, 1997). The evidence indicates the viability of the local population and provides an argument in favour of decreasing the rank of the species by one point in the Red Data Book of Karelia. The park has a total of 26 indicator species including some rare calicioid lichens and fungi such as *Chaenotheca gracillima* (Vain.) Tibell*, Ch. subroscida* (Eith.) Zahlbr.*, Chaenothecopsis viridialba* (Kremp.) A.F.W.Schmidt*, Cybebe gracilenta* (Ach.) Tibell. and *Cyphelium inquinans* (Sm.) Trevis. Species indicative of old-growth forests, e.g. *Alectoria sarmentosa, Bryoria fremontii, Evernia mesomorpha, Lobaria pulmonaria, L. scrobiculata* and *Nephroma bellum*, are common.

Situated in the White Sea, the **Kuzov Reserve** was set up to protect island flora and fauna. On the ten islands that form the eastern archipelago cliffs rise up tens of metres above the sea. The vegetation cover is composed of tundra-like dwarf shrub communities where mosses and lichens combine with lithic groups growing on moss- and lichen-covered rocks. Micromires are commonplace in practically all landform depressions (Biodiversity inventories..., 1999). Floral belts are distinct in the largest Russkiy and Nemetskiy Kuzov islands where coniferous, mixed and deciduous stands, including primary stands of mountain birch, grow and highly productive forests occur at the foot of hills.

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[1] Also found by M. Kuusinen near Kostomuksha (the written report).

[2] Also found by M. Kuusinen near Kostomuksha (the written report), probable frequent in humid spruce forests at least in Kpoc.

On Nemetskiy Kuzov young stands of Siberian pine *(Pinus sibirica)* grow well and one very old individual tree planted by the monks of the Solovetsk Monastery still survives. Bergroth (1895) was the first to survey the lichen flora of the Kuzov islands and presented evidence for the occurrence of *Sphaerophorus globosus* (Huds.) in the area. More recently Savicz (1912) studied samples collected by R. R. Pohle from the White Sea shore and from some of the islands mainly in the Archangel region and reported 15 lichen species from the islands of Lodeynyy, Nemetskiy and Russkiy (Bolshoi) Kuzov. Together with A. Kravchenko's collections from Nemetskiy and Russkiy Kuzov islands, the Voroni islands, the islands of Verkhniy, Sredniy, Zhiloy, Oleshin, Kurichya Nilaksa and Lodeynyy, a total of 59 lichen species is now known (Table 23), 6 species being reported for the first time for the Kpoc province. The species composition of lichens reflects the environmental pattern of the territory. Both tundra and typical forest lichens are present. Of particular interest are certain rare lichens such as *Alectoria sarmentosa* subsp. *vexillifera* and *Ramalina roesleri* (Hochst. ex Schaer.) Hue. *Ramalina roesleri* was encountered on Nemetskiy Kuzov in 1994 (on an old Siberian pine) and again in 2000. Except for *Hypogymnia vittata* (Ach.) Parrique and *Omphalina hudsoniana* which may have been overlooked by collectors and *Peltigera polydactyla* (Neck.) Hoffm., all of the species mentioned by V.P. Savicz still grow in the Kuzov Reserve. The presence of stabile conditions favourable for the long-term evolution of lichen communities is indicative of the value of this area and of the importance of assigning it protected status.

The **Kizhi Reserve** is made up of the Kizhi Islands which incorporate the historically and culturally valuable Kizhi Museum Reserve and its protection zone. The central part of the archipelago consists of more than ten islands which have been subject to varying degrees of anthropological interference. These include Kizhi, Bolshoi Klimenetskiy, Severnyi, Yuzhnyi Oleniy, and Volkostrov. This largely explains the highly characteristic lichen flora of the reserve where dominant species associated with natural and slightly disturbed habitats are enriched by lichens associated with inhabited areas. As early as the late 19th century Nylander (1866) and Norrlin (1876) published a report on the material collected by T. Simming and A. Kullhem in 1863 and recorded 18 lichen species for Kizhi and Bolshoi Klimenetskiy islands. These included *Evernia divaricata* (Kizhi Island) and *Dimerella lutea* (Dicks.) Trevis etc. These are the only finds of *Dimerella lutea* recorded in Karelia. Both our own evidence and earlier data (Inventory and study.., 2000) suggest that the reserve contains 96 lichen species (Table 23), five of which are recorded for the first time for Kon province. Found growing on elm trees along the shore on Kizhi Island, [3]*Gyalecta truncigena* (Ach.) Hepp[3] had not been previously reported anywhere in Karelia. The finds of *Ramalina sinensis* Jatta on Volkostrov and Bolshoi Klimenetskiy are also of interest. This lichen was found earlier in the Vodlozersky National Park (Fadeeva et al., 1997). Owing to its scarcity on north shore of Ladoga Lake Finnish botanists (Oksanen & Vitikainen, 1999) proposed its inclusion in the Red Data Book of Karelia as a declining species. The reserve also contains ten old forest indicator species, the most common being *Leptogium saturninum, Lobaria pulmonaria, Nephroma bellum* and *Ramalina dilacerata*. We think that *Nephroma bellum* and *Ramalina dilacerata*, which are found in most of the strictly protected areas (see present paper), should be deleted from the list of protected Karelian lichens.

The **Valaam Archipelago Nature Park** with its unique historical, environmental and landscape features covers over fifty islands that together make up the Valaam Archipelago. The largest islands are those of Valaam and Skitsky. The pine and spruce stands growing there vary in age from 120 to over 200 years. Introduced species such Siberian pine, English oak *(Quercus robur)*, Siberian fir *(Abies sibirica)* and Siberian larch are well represented (Ecosystems of Valaam .., 1989). According to available evidence (Makhmudova & Himelbrant, 1992) the lichen flora of the Valaam Archipelago extends to 232 species. Of special interest are the finds of the rare lichens *Cetrelia cetrarioides* (Duby) W.L. Culb. & C.F.Culb., *Parmelina tiliacea* (Hoffm.) Hale, *Ramalina roesleri* and *Ramalina thrausta.* According to recent studies this is the only habitat in Karelia supporting *Cetrelia cetrarioides* and *Parmelina tiliacea*. *Cladonia borealis* (colls.: I.A. Dushak & L.A. Morozova, 1985) and *C. novochlorophaea* (Sipman) Brodo & Ahti (colls.: I.A. Dushak & L.A. Morozova, 1985; A.V. Kravchenko, 1993) were identified by T. Ahti at the Forest Research Institute Herbarium (PTZ) in 2000. Both of these species are new to the province. Moreover, *C. novochlorophaea* is recorded here for the first time in Karelia.

To sum up, as a result of the inventory study of Karelian lichens in certain strictly protected areas three new species have been found; 21 species have been reported for the first time for Kpoc province and 5 for Kon province. On the basis of the new evidence for the distribution of rare and endangered lichens a proposal has been made to revise the list of lichens and to more precisely evaluate the status of certain lichen species listed in the Red Data Book of Karelia.

It is clear from this brief review that the lichens of Karelia have not all been subject of equally detailed study. We know little about certain species found in SPAs where our inventory has just begun. At the same time our work has shown that the existing and proposed reserves can help maintain the biological diversity of Karelia. When we know the composition of lichen floras in the SPAs we will be able to fully assess the lichen diversity of Karelia to a first approximation.

The author wishes to thank A.V. Kravchenko for his field work collecting lichen samples during numerous expeditions to various parts of Karelia and his contribution to the collection of the Lichenological Herbarium at the Forest Research Institute, KRC, RAN (PTZ).

The author is indebted to Prof. T. Ahti of the University of Helsinki, Finland, who visited Petrozavodsk in July 2000, examined a collection of lichens at the Forest Research Institute, especially species of the genus Cladonia, and identified and re-identified many lichen samples.

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[3] Have been identified by T. Ahti.

Table 23

Lichens in Karelia's protected areas (Kalevala National Park, Kuzov Reserve and Kizhi Reserve)

Lichen species	Kpoc		Kon
	Kalevala National Park	Reserve	
		Kuzov	Kizhi
Acarospora fuscata (Nyl.) Arnold			(++)+
A. smaragdula (Wahlenb.) A. Massal. var. smaragdula			(++)
A. nigricans (Ach.)Nyl.		(++)	
A. ochroleuca (Hoffm.) A.Massal.		++	
•*A. sarmentosa* (Ach.) Ach. subsp. sarmentosa	+		
A. sarmentosa (Ach.) Ach. subsp. vexillifera (RBK. 3). (RBEF. 3)		++**	
Amandinea punctata (Hoffm.) Coppins & Scheid.	+		+
Arctoparmelia centrifuga (L.)Hale	+	++	
Arthonia cinereopruinosa Schaer.			(++)
•*A. incarnata* Th.Fr. ex Almq. (RBEF)	+		
A. spadicea Leight.			(++)
Aspicilia caesiocinerea (Nyl. ex Malbr.) Arnold			+
A. cinerea (L.) Körb.	+		
A. obscurata (Fr.) Arnold			(++)
Bacidia bagliettoana (A.Massal. & De Not) Jatta			+
B. subincompta (Nyl.) Arnold	+**		
Baeomyces carneus Flörke	+		
B. rufus (Huds.) Rebent.	+		
Biatora efflorescens (Hedl.) Räsänen	+**		
Bryocaulon divergens (Ach.) Kärnefelt		(++) ++	
Bryoria capillaris (Ach.) Brodo & D. Hawksw.	(+) +		
B. fremontii (Tuck.) Brodo & D.Hawksw. (RBR. 2). (RBK. 4).	+		
B. furcellata (Fr.) Brodo & D.Hawksw.	+		+
B. fuscescens (Gyeln.) Brodo & D.Hawksw.	(+) +		
B. cf. implexa (Hoffm.) Brodo & D.Hawksw.	+**		
B. simplicior (Vain.) Brodo & D. Hawksw.	+		
Buellia disciformis (Fr.)Mudd	+		
Calicium denigratum (Vain.)Tibell	+**		
C. salicinum Pers.			(++)
C. trabinellum (Ach.) Ach.	+		
Caloplaca holocarpa (Hoffm.) A.E.Wade	(+)		
Candelariella xanthostigma (Ach.) Lettau			+
C. vitellina (Hoffm.) Müll. Arg.	+		
Catillaria erysiboides (Nyl.) Th. Fr.			(++)
Cetraria aculeata (Schreb.) Fr.		(++) ++	
C. ericetorum Opiz.	+		+
C. islandica (L.) Ach. subsp. crispiformis		++	
C. islandica (L.) Ach. subsp. islandica	(+) +	++	+
C. sepincola (Ehrh.) Ach.	+		+
C. delisei (Bory ex Schaer.) Kärnefelt & Tell		++	
C. fastigiata (Delise ex Nyl.) Kärnefelt & Tell		++	
Chaenotheca brachypoda (Ach.) Tibell	+**		
C. brunneola (Ach.) Müll. Arg.	+**		
C. chrysocephala (Turner ex Ach.) Th.Fr.	+		
C. ferruginea (Turner &Borrer) Mig.			(++)
C. furfuracea (L.) Tibell	+**	Pcell +	
Cladina arbuscula (Wallr.) Hale & W.L.Culb. subsp. squarrosa (Wallr.) Burgaz.	+	(++) ++	+
C. mitis (Sandst.) Mong.	(+) +	++	
C. rangiferina (L.) Nyl.	+		+
C. stellaris (Opiz)Brodo	+	++	+
C. stygia (Ach.) Ahti	+**	++	
Cladonia amaurocraea (Flörke) Schaer.	+	(++) ++	
C. bacilliformis (Nyl.) Glück	+		
C. bellidiflora (Ach.) Schaer.		(++) ++	
C. borealis S. Stenroos	+		
C. botrytes (K.G.Hagen) Willd.	(+) +	++	
C. cenotea (Ach.) Schaer.	+		
C. cervicornis (Ach.)Flot. subsp. verticillata (Hoffm.)Ahti	+		
C. chlorophaea (Flörke ex Sommerf.) Spreng. s. str.			+
C. coniocraea (Flörke) Spreng.	+		
C. cornuta (L.) Hoffm.	+	++	+
C. crispata (Ach.)Flot. s. lat.	+	++	
C. deformis (L.) Hoffm.	+		
Cladonia fimbriata (L.) Fr.	(+) +		
C. furcata (Huds.) Schrad.	(+) +	(++) ++	+
Cladonia gracilis (L.) Willd. subsp.gracilis		(++) ++	
C. gracilis (L.) Willd. subsp. turbinata (Ach.) Ahti	(+) +		
C. macilenta Hoffm. (RBF)	(+) +		
C. phyllophora Hoffm.			+

Lichen species	Kpoc		Kon
	Kalevala National Park	Reserve	
		Kuzov	Kizhi
C. pyxidata (L.) Hoffm.	+		
C. squamosa (Scop.) Hoffm.		(++) ++	
C. sulphurina (Michx) Fr.	+		
C. symphycarpia (Flörke) Fr.			+
C. uncialis (L.) F.H. Wigg. subsp. uncialis	+	++	+
Cliostomum leprosum (Räsänen)Holien & Tønsberg	+		
Dermatocarpon luridum (With.) J.R.Laundon (RBEF. 4)	+		
Dimerella lutea (Dicks.) Trevis.			(++)
D. pineti (Ach.) Vĕzda			(++)
•*Evernia divaricata* (L.) Ach. (RBK. 3). (RBEF. 3)	+		(++)
•*E. mesomorpha* Nyl.	+		+
E. prunastri (L.) Ach.	(+) +		+
Flavocetraria cucullata (Bellardi) Kärnefelt & Tell		++	
F. nivalis (L.) Kärnefelt & Tell		(++) ++	
Fuscidea pusilla Tønsberg	+*		
Graphis scripta (L.) Ach.			(++)+
Gyalecta cf. truncigena (Ach.) Hepp			+*
Hypocenomyce scalaris (Ach.) Choisy	+		
Hypogymnia physodes (L.) Nyl.	(+) +	++	+
H. tubulosa (Schaer.) Hav.	(+) +		+
•*H. vittata* (Ach.)Parrique	+	(++)	
•*Icmadophila ericetorum* (L.)Zahlbr.	+		
Imshaugia aleurites (Ach.) S.L.F. Meyer	(+) +		
Lecanora allophana Nyl.	+		+
L. cateilea (Ach.) A. Massal.	+**		
L. circumborealis Brodo & Vitik.	+		
L. hypopta (Ach.) Vain.	+		
L. leptyrodes (Nyl.) Degel.			+**
L. pulicaris (Pers.) Ach.	+		
L. symmicta (Ach.) Ach.	(+) +		+
Lecidea erythrophaea Sommerf.	+		+
Lecidella euphorea (Flörke) Hertel	+		
Lepraria incana (L.) Ach.. coll.	+		
•*Leptogium saturninum* (Dick.)Nyl.	+		+
•*Lobaria pulmonaria* (L.) Hoffm. (RBR. 2). (RBK. 4)	+		+
•*L. scrobiculata* (Scop.) DC. (RBK. 3). (RBEF. 3)		(++) ++	
•*Lopadium disciforme* (Flot.)Kullh.	+		
Loxospora elatina (Ach.) A.Massal.	+**		
Melanelia exasperata (De Not.) Essl.			(++)+
M. commixta (Nyl.) Thell	+		
M. hepatizon (Ach.) Thell		++**	+**
M. olivacea (L.) Essl.	+		+
M. sorediata (Ach.) Goward & Ahti	(+) +		+
M. stygia (L.)Essl.	+	++	
*M. subargentifera (*Nyl.) Essl.			+
M. subaurifera (Nyl.) Essl.	+		
Micarea denigrata (Fr.)Hedl.	+		
Mycobilimbia carneoalbida (Müll.Arg.) comb. ined.	+		+
M. epixanthoides (Nyl.) comb. ined.	+		+
Mycoblastus alpinus (Fr.) Kernst.	+*		
M. sanguinarius (L.) Norman	+		+
Nephroma arcticum (L.) Torss.	+	(++) ++	
•*N. bellum* (Spreng.)Tuck. (RBK. 2)	+		
•*N. parile* (Ach.) Ach.	+		+
•*N. resupinatum* (L.) Ach.	+		+
Ochrolechia androgyna (Hoffm.) Arnold	+		
O. frigida (Sw.) Lynge		++	
O. microstictoides Räsänen	(+)		
Omphalina hudsoniana (H.S. Jenn.) H.E. Bigelow (RBR. 3). (RBK. 3). (RBEF. 3)		(++)	
Opegrapha varia Pers. var. varia			(++)+
Ophioparma ventosa (L.) Norman		(++) ++	
•*Pannaria pezizoides* (G.Weber)Trevis.	+		
Parmelia fraudans (Nyl.)Nyl.			+
P. saxatilis (L.) Ach.	+	(++) ++	+
P. sulcata Taylor	(+) +	++	+
•*Parmeliella triptophylla* (Ach.)Müll.Arg.	+**		
Parmeliopsis ambigua (Wulfen) Nyl.	+		+
P. hyperopta (Ach.) Arnold	+		+
•*Peltigera aphthosa* (L.) Willd.	+	++	+
•*P. canina* (L.) Willd.	+		+
P. degenii Gyeln. (RBK. 3). (RBEF. 3)	+**		+**
P. didactyla (With.) J.R.Laundon	(+)		

End. table 23

Lichen species	Kpoc		Kon
	Kalevala National Park	Reserve	
		Kuzov	Kizhi
P. lepidophora (Nyl. ex Vain.) Bitter	+**		+
•*P. leucophlebia* (Nyl.) Gyeln.	+	++	+
P. malacea (Ach.) Funck	(+)		
P. membranacea (Ach.) Nyl.			+**
P. neckeri Hepp ex Müll. Arg.	+**	++	+
P. neopolydactyla (Gyeln.) Gyeln.	+	++	+
P. polydactyla (Neck.)Hoffm.	+	(++)	+
•*P. praetextata* (Sommerf.) Zopf.	+		+
P. rufescens (Weiss.) Humb.	(+) +		+
P. scabrosa Th. Fr.	+	(++) ++	
Pertusaria amara (Ach.) Nyl.	+		
P. ophthalmiza (Nyl.) Nyl.	+**		
Phaeophyscia ciliata (Hoffm.) Moberg	(+) +		
P. orbicularis (Neck.) Moberg	(+)		+
Phlyctis argena (Spreng.) Flot.	+		+
Physcia stellaris (L.) Nyl.	(+) +		+
P. adscendens H.Olivier			+
P. aipolia (Ehrh. ex Humb.) Fürnr. var. aipolia	(+)		
P. aipolia (Ehrh. ex Humb.) Fürnr. var. alnophila (Vain. Lynge	(+)	++	+
P. caesia (Hoffm.) Fürnr.		++	+
P. tenella (Scop.) DC var. tenella			+
Physconia distorta (With.) J.R.Laundon			+
P. perisidiosa (Erichsen) Moberg			+
Platismatia glauca (L.) W.L.Culb. & C.F.Culb.	+		
Pseudephebe pubescens (L.) M. Choisy		++**	
Psilolechia lucida (Ach.)M. Choisy			(++)
•*Ramalina dilacerata* (Hoffm.) Hoffm. (RBK. 4)	+		+
R. farinacea (Westr.) Ach.		++	+
R. pollinaria (Westr.)Ach.		++**	+
R. polymorpha (Lilj.) Ach.		++	
R. roesleri (Hochst. ex Schaer.) Hue (RBK. 4). (RBEF. ?)		++**	
R. sinensis Jatta			+
Rhizocarpon geographicum (L.) DC. s. lat.	+		
Rimularia insularis (Nyl.) Hertel & Rambold			(++)
•*Rinodina cinereovirens* (Vain.) Vain.	+		
R. exigua Gray			+
R. pyrina (Ach.) Arnold			+
R. sophodes (Ach.) A.Massal.	+		
Scoliciosporum chlorococcum (Stenh.) Vĕzda			+
Sphaerophorus globosus (Huds.) Vain.		(++) ++	
S. fragilis (L.) Pers.		(++) ++	
Stereocaulon cf. grande (H. Magn.) H.Magn. (RBEF. 4)	+		
S. saxatile H.Magn.	+		
S. subcoralloides (Nyl.) Nyl.	(+)		+**
S. tomentosum Fr.	+		
Thamnolia vermicularis (Sw.)Schaer.		++**	
Thelomma ocellatum (Körb.)Tibell	(+)		
Trapeliopsis granulosa (Hoffm.) Lumbsch.	(+)		(++)
Tuckermannopsis chlorophylla (Willd.)Hale	(+) +		+
Umbilicaria deusta (L.) Baumg.	+	++	+
U. hirsuta (Westr.) Hoffm.		++	
U. hyperborea (Ach.) Hoffm.	+	(++) ++	
U. proboscidea (L.) Schrad.		++	
U. torrefacta (Lightf.) Schrad.		++	
Usnea hirta (L.) F.H.Wigg.	(+) +		+
U. subfloridana Stirt.	+		
U. filipendula Stirt.	+		
Vulpicida pinastri (Scop.) J.E.Mattsson & M.J.Lai	(+) +		+
Xanthoparmelia conspersa (Ach.) Hale	+	(++) ++	+
Xanthoria candelaria (L.)Th.Fr.	(+)	++	+
X. parietina (L.) Th.Fr.	(+)		(++)+
X. polycarpa (Hoffm.)Th.Fr. ex Rieber			+
Xylographa parallela (Ach.: Fr.) Behlen & Desberg	+		
Total	139	59	96

Note: Biogeographic provinces: Kon = Karelia onegensis; Kpoc = Karelia pomorica occidentalis Symbols:

• old-growth forest indicator species:

RBK = species listed in the Red Data Book of Karelia; RBR = species listed in the Red Data Book of Russia; RBEF = species listed in the Red Data Book of East Fennoscandia.

\+ author's collection, ++ A.V. Kravchenko's collection, (+) species referred to by T. Ahti, (++) species described in other literature.

* reported for the first time in Karelia, ** reported for the first time in the biogeographic province.

3.5. Mammal species composition, areal dynamics, populations and protection

Introduction. Many recent publications and handbooks have reported substantial changes in the composition of fauna and the distribution of individual mammal species in North Europe. These changes have resulted from a number of factors, the transformation of habitats by human activities being the most important at the present time. When the ecological environment changes rapidly over a large area, primeval ecosystems are fragmented or destroyed and derivative ecosystems are formed in which original species may not survive. Furthermore, these derivative ecosystems are occupied by new species – representatives of other faunistic complexes.

The distribution of animals is also affected markedly by annual and long-term natural variations in population sizes. The accumulation of so-called population 'reserves', the artificial maintenance of the high population density of animals hunted by man in some areas, the introduction of new species and animal protection are also important factors affecting population dynamics.

The landscapes of Karelia have changed greatly during the past century. Primeval forests that once covered large areas have been cut down to give way to secondary forests dominated by unevenly aged deciduous and mixed stands. With the expansion of agricultural lands chiefly through mire reclamation the total area of mire land has diminished. Forest reclamation and other activities have markedly transformed paludified forests over large areas as well as affecting the distribution, exploitation and protection of mammal fauna. This article seeks to review current information concerning the dynamics of certain wildlife species in Karelia and draw comparisons between Karelia and its western neighbour, Finland. We have concentrated on mammal species for which information is readily available and the examples provided are those which are most familiar to us. Smaller mammal species of lesser interest from the management point of view receive less attention.

Wolf and moose. Wolf (*Canis lupus* L.) and moose (*Alces alces* L.) were the first species to be affected by the above-mentioned changes in the environment. Wolves were not seen throughout the 1920s and 1930s in most of Murmansk Province and in northern Karelia. Instead they occupied areas where livestock rearing and reindeer husbandry were well development – Zaonezhye, Prionezhye, Priladozhye, Barents Sea and White Sea coasts.

Large-scale commercial forest management of northern Russia began in the 1940s. Deciduous species which colonised much of the deforested area provided favourable habitats for moose. This took between seven and ten years after felling operations in southern Karelia while the corresponding period in northern Karelia was ten to fifteen years. This together with the prohibition of hunting resulted in increased moose populations. A stable supply of food was thereby provided for the wolf and by the mid 1960s this predator had penetrated northern Karelia and the southern part of Murmansk Province. The appearance of wolves in the north taiga zone was also favoured by the development of the road network, especially logging tracks, which allowed animals to move more easily during times of deep snow (Danilov, 1981, 1987, 1994).

Species with growing ranges. Other species enjoying rapid spreading are the mole (*Talpa europaea* L.), hedgehog (*Erinaceus europaeus* L.), birch mouse (*Sicista betulina* Pall.), common field mouse (*Microtus arvalis* Pall.), harvest mouse (*Micromys minutus* Pall.), polecat (*Mustela putorius* L.), badger (*Meles meles* L.), roe deer (*Capreolus capreolus* L.) and wild boar (*Sus scrofa* L.). The reasons for these increases include changes in forest landscape structure as well as the influence of other factors.

The wild boar was first reported in Karelia in the late 1960s and had reached the Arctic Circle by the early 1970s (Danilov, 1979). However, after this rapid colonisation the wild boar has declined in northern Karelia. In the districts of Louhi, Kem and Muezersky the species has not been encountered during wintertime since 1998. The only evidence for its presence was the identification by A.V. Yakimov of wild boar tracks in the winter of 1992 twenty kilometres north-west of Muezersky. In the Kalevala district wild boar was reported in the vicinity of Luvozero (1988) and Pikhtozero (1992). A litter of young wild boars was seen near Luusalma in the late 1980s and two large adults were encountered in the vicinity of Kalevala in the autumn-winter of 2000–2001. The hunting specialist O. A. Mishukov saw a female with seven young pigs in the late 1980s near Yukovo, Belomorsk district. Over the past few years between five and seven animals have been observed in the area of Kolezhma. Wild boars are common in the southern part of Suojärvi district and in the districts of Kondopoga and Medvezhegorsk. Thus, in Zaonezhye, where wild boars are fairly common during the summer season (an average of 0.54 animal per 1 000 ha during 1996–1999), a group of twenty-six animals of various ages was seen near Kuzaranda in the spring of 1999 (hunter A. I. Kamaev, pers. med.). In the winter of 1991–1992 the hunter S.V. Yershov came across wild boar tracks south of Lake Verkhneye Kumozero (Louhi district) and 10 km north of Avneporog in Kem district. In 1992 attempts were made to shoot two adult wild boars on the Chupa-Plotina highway in the Louhi district while in November 1998 an adult male wild boar was killed by a vehicle on the St. Petersburg-Murmansk highway. Wild boar is more common in southern Karelia where it mainly inhabits well-developed agricultural areas. However, even here it is unevenly distributed.

The polecat continues to spread northwards (Fig. 42). During the period 1988–2000 polecat tracks were found near Luvozero in the southern Kalevala district. In 1987 and 1993 polecats were trapped in the same area and also 30–40 km away in Kontokki, Nyuk-ozero (Pozdnyakov, 1997). In 1989 and 1990 two animals were trapped in the vicinity of Reboly. Over the past decade polecats sightings have also been made on the White Sea coast in the Belomorsk district mostly near the River Shuya (1988) and in the surrounding settlements of Khvoiny (1993), Viremga and Malenga (1994), and Sumposad (1997). In the 1980 polecats were the target of hunters in the area of Yukovo (2 animals), Lapino (3) and Vorenzha (1). In the districts of Muezerka and especially of Segezha polecats are more common although even at these locations sightings are not made every year. This is in spite of the fact that during the late 1980s some 20–30 polecat pelts were produced in the Segezha district with no less than 45 pelts in 1987.

Snow track counts and pelt data show that the European hare (*Lepus europaeus* L.) has become more common in southern Karelia. Its tracks were found near Sortavala in 1986, in the Lahdenpohja district in 1988, in the Olonets and Pudozh districts in 1993, in the Pitkaranta and Lahdenpohja districts in 1994, in the Pudozh and Lahdenpohja districts in 1995 and in the Lahdenpohja district in 1997.

With recordings of mountain hare tracks in the above districts as few as 6.9–15.1 tracks per 10 km, the ratio between European hare and mountain hare track density varies between 1: 60 to 1: 950 (Bmoosein, 1999). The European hare is most common in the Lahdenpohja district and is found chiefly in the vicinity of the Kurkijoki, Hiitola, Jakkimsky, Taunan and Elisenvaara settlements. In the 1930s when European hare population were relatively large the European hare and mountain hare pelt ratio varied from between 1: 47 to 1: 95 in southern Karelia. In some districts European hare pelts were regularly produced. However, present day populations are less predictable.

The European hare is no longer found in the Medvezhyegorsk and Pryazha districts where it was already scarce by the 1930s. In the 1970s a single sighting was made in the Kondopoga district near Tul-guba. A few hares were killed by hunters near Tarzhepol and Uzheselga in the Prionezhsky district.

European hare populations are unlikely to increase much over the next few years. In the past few decades their preferred habitats, i.e. grain crop lands mostly reclaimed from former mire sites, have virtually disappeared. Thus, while 1928 these covered 47 000 ha and in 1943 43 000 ha today they account for area of not more than 1 000 ha.

Declining species. Most north-taiga animals tend not to colonise more southerly areas. On the contrary, some of them have actually retreated further north. Both the wolverine (*Gulo gulo* L.) and the forest reindeer (*Rangifer tarandus fennicus* Lonnb.) respond in this manner to human threat and to various other activities relating mostly to the large-scale construction of country houses and the recreational use of forests.

Our data indicates that the decline in the distribution and population of the wolverine is chiefly due to the use of poison intended to combat wolves (1960s to early 1980s) and the use of snowmobiles for chasing animals (Danilov, 1994, 1995). However, a few tracks were found near Hiitola in the Lahdenpohja district (1988), near Vartsila in the Sortavala district (1988), in the vicinity of Kotkozero and Verkhny Olonets in the Olonets district (1989) and near Shoksha in the Prionezhsky district (1990). Wolverine footprints were more regularly observed near Vidany (1992), Kroshnozero (1994), Kutizhma (1996), Lake Syamozero (1994 and 1998) and Kudama (2000) in the Pryazha district.

Significant changes have also taken place in the wild forest reindeer population. In areas where domestic reindeer breeding and, consequently, the hunting and killing of wild animals by reindeer breeders have stopped, the populations and distribution of wild forest reindeer have quickly recovered. Thus, by the mid 1970s the reindeer population had increased to 6 000 animals and its southern distribution boundary pushed forward to the Kuolisma-Porosozero-Maselgskaya line and the shore of Lake Onega as far as the administrative border of the Vologda Province (Danilov, 1975a, 1975b; Danilov et al., 1986) (Fig. 43). However, the social changes which began in Russia in the late 1980s and early 1990s triggered unprecedented levels of illegal hunting in Karelia and in other parts of the country.

As a consequence the wild forest reindeer population of Karelia has fallen to a little more than 3,000 individuals and its southern distribution boundary has retreated northwards almost as far as Segezha while in southern Karelia its area of distribution has been fragmented (Danilov et al., 2001). During the period 1988–2000 the southernmost sightings of wild forest reindeers were made in the areas of Maslozero, Ogorelyshi and Sergievo in the Medvezhegorsk district, in Porosozero, Kudom Guba and Gimoly in the Suojärvi district, and in Kugonavolok, Yangozero, Pyalma and Pudozh-Gora in the Pudozh district.

Changes in the distribution of lynx (*Lynx lynx*) present an irregular pattern. Lynx are occasionally reported in northern Karelia although not every year. At the same time its northern boundary fluctuates. Thus, during thirty-five years of observations made in the Louhi district (bordering the Murmansk Province) lynx tracks were observed only in the late 1960s and early 1970s, again in the mid to late 1980s and then in the late 1990s. This seven to ten year periodicity is presumably related to variations in the populations of the mountain hare, the main prey of lynx in the north taiga (Fig. 44). The mountain hare was most prolific in Karelia during the early 1960s, 1970s and 1980s. Accordingly, lynx populations peaked during the middle parts of these periods (Fig. 44). Our evidence suggests that young animals migrate from southern Karelia to northern Karelia when the food supply is favourable (Danilov et al., 2001).

Introduced species. As noted above, mammal fauna is significantly affected by the introduction of new species. The first attempts of this kind in Karelia was made in 1932 when the muskrat (*Ondatra zibethica* L.) was released into the Pudozh district. Following more recent releases and natural dispersal the muskrat has now spread both throughout and outside Karelia.

In 1934 a small number of American minks (*Mustela vison* Schreb.) was set free near to Petrozavodsk. Today this species is common in Karelia. Our studies have shown that the minks have acclimatised successfully mostly because the natural population was regularly enriched by immigrants from fur farms (Danilov, 1964, 1969, 1972a).

The invasion of Karelia by the American mink was disastrous for the European mink (*Mustela lutreola* L.), an aboriginal species of Karelia. Indeed, the European mink has since vanished from Karelia although it is presumed to inhabit the north-eastern part of the Pudozh district near the border between Karelia and Arkhangelsk Province. Probably for the same reason the European mink is no longer found in Leningrad Province, over much of the Novgorod, Pskov, Vologda and Tver provinces or in Finland (Danilov & Tumanov, 1976; Danilov, 1992; Kauhala, 1996).

In the early 1950s another North American species, the Canadian beaver (*Castor canadensis* Kuhl.) arrived in Karelia. Beavers were released in Finland and then migrated across the border into Russian Karelia. They spread both naturally and with human help over most of Karelia. Today there are over 4 000 Canadian beavers in Karelia.

Only ten years after the arrival of the Canadian beaver Karelia became a home once again for the European beaver (*Castor fiber* L.) which spread from Leningrad Province (Danilov, 1972b, 1975c). The European beaver had inhabited Karelia in the past and the history of the species in the area is well known (Danilov, 1976; Danilov, Kan'shiev, 1983).

An inventory conducted in 1999–2000 showed that Karelia has no more than 1 500 European beavers. The penetration of one species into the distribution area of another species is likely to trigger interspecific competition and the ousting of one species by another. Finnish experience suggests that the Canadian beaver is likely to oust its European relative from Karelia (Danilov et al., 2000).

As a result of the acclimatisation and natural dispersal of animals the mammal fauna of Karelia has been enriched by seven new species, namely the muskrat, American mink, raccoon dog (*Nyctereutes procyonoides* Gray.), Canadian and European beaver, wild boar and roe deer. With the exception of the roe deer, these have spread throughout Karelia. The roe deer is not reported every year and lives mainly in southern Karelia (Danilov, 1974; 1979). In the Murmansk Province some introduced species, e.g. muskrat and American mink, have become quite common. However, the raccoon dog has not adapted itself to the local environment, the future of the European beaver is uncertain and the roe deer is only occasionally encountered (Semenov-Tyan-Shansky, 1982; Kataev, 1998).

In addition to the above seven species, white-tailed deer (*Odocoileus virginianus* Zimm.), fallow deer (*Cervus dama* L.) and mouflon (*Ovis musimon* Pall.) have acclimatised to Finnish conditions. The wild forest reindeer has returned from Russian Karelia through natural colonisation. This last-mentioned species was also reintroduced to south-western Finland. The fallow deer population is very small. Thus, Finland's theriofauna has changed more considerably than that of Karelia while in Murmansk Province mammal populations have not been subject to substantial changes (Bmoosein et al., 1999).

Population variability. Analysis of variations in the distribution and numbers of animal species hunted by man has shown that the entire terrestrial vertebrate population of north-western Russia and Fennoscandia is highly dynamic and even unstable. A similar pattern is likely to be associated with other groups of animals.

This process is strikingly heterogeneous. Some species show a clear tendency to move northwards while others go south and west. Some mammal populations fluctuate, continuous areas are broken into fragments and then again become continuous. The ongoing processes are obviously largely due to the young age of the terrestrial vertebrate fauna of Fennoscandia and to major antropogenic changes in the environment.

All the animal species studied vary in prolificacy. Some variations are mainly the result of natural factors, their effects on animal populations often being periodic. The direct impact of hunting in the study area and throughout North European Russia is relatively minor and does not account for large-scale population fluctuations. Game animal species may be divided into three groups according to the pattern of changes in their populations (Danilov et al., 1998).

Group 1 includes the red squirrel (*Sciurus vulgaris* L.), mountain hare (*Lepus timidus* L.), red fox (*Vulpes vulpes* L.), weasel (*Mustela nivalis* L.), stoat (*Mustela erminea* L.), polecat and lynx. The population levels of most predators in this group depend directly on those of their main prey.

Group 2 comprises species affected by both natural (but not periodic) and anthropogenic factors. It includes animals hunted by man such as the moose, wild forest reindeer, wild boar and various large predators such as the wolf and wolverine which compete with man for hoofed animals.

Group 3 is made up of the muskrat, beaver, American mink, pine marten (*Martes martes* L.) and brown bear (*Ursus arctos* L.). These are affected by hunting to the same degree as the aforementioned mammals but the impact of hunting varies according to fluctuations in the demand for their pelts. The brown bear could also be placed in group 2 as it plays an important role as a predator in controlling moose populations. Cyclic variations in prolificacy are not typical of this group.

Comparison between Karelia and Finland. Analysis of the data obtained during our large-scale monitoring of animals hunted by man (Danilov et al., 1996, 1997, 1998, 1999, 2000; Helle et al., 1997, 1998, 1999, 2000) in East Fennoscandia (Republic of Karelia and Finland) indicates that species composition varies little over most of the region except for the Russian-Finnish border where appreciable differences occur (Linden et al., 2001). The border divides the moose into two populations inhabiting relatively similar environments. However, the impact of human activities on the moose and its habitats differs significantly from one side of the border to the other. These differences are a result of historic, cultural, economic and social factors and have led to differences in the distribution, population and form of human exploitation (Fig. 45).

Many medium-sized predators are more prolific in Finland as they thrive on deforested and agricultural lands which cover larger areas in Finland than in Karelia (Henttonen, 1989). Extensive forest management results in changes in the species composition of small mammal communities. For example, voles of the *Cletriomys* genus typical of forest fauna give way to voles of the *Microtus* genus. It is clear that the forest management methods used nowadays in Finland serve to increase the number of voles and their predators. Thus, the red fox is far more common in Finland than in Russian Karelia (Fig. 46) (Linden et al., 2000).

A comparison of the estimated population levels of twenty-four species in Russian Karelia and Finland allows the following six categories to be drawn up (Danilov et al., 1997);

1. Species which are far more common in Karelia: wolf, brown bear, polecat and wolverine (Fig. 47);
2. Species which are more common in Karelia: wild boar and forest reindeer;
3. Species which are more or less equally common to both countries: stoat (Fig. 48), American mink, pine marten, lynx, red squirrel (Fig. 49), European and Canadian beaver;
4. Species which are more common in Finland: mountain hare (Fig. 50), raccoon dog, red fox, weasel, moose and otter;
5. Species which are far more common in Finland: European hare and roe deer;
6. Species which live only in Finland: fallow deer, white-tailed deer and mouflon.

Average species diversity as given by the number of species (out of twenty selected wildlife species) present in any given area of 50 x 50 km is much higher in Russian Karelia (17.8) than in Finland (14.9) (Linden et al., 2000). This difference is of the order of 20% and is mostly accounted for by the presence or absence of particular forest species.

Forest reindeer, wolverine, pine marten and squirrel occur in greater numbers in the mature primeval forests growing along the border zone in Karelia. In Finland, especially in its northern part with well-developed agriculture, the mountain hare, red fox and lynx are far more common than in areas of Russian Karelia of corresponding latitude. Similarly, the distribution boundary of lynx is much farther north in Finland than in the Kola Peninsula.

Conservation. Over the past decade the populations of some of the large predators such as the wolf, brown bear and wolverine have grown rapidly in Finland as a result of their protection. As a consequence the moose population of north-eastern Finland has fallen.

In both Russian Karelia and Finland attitudes towards species listed in the Red Data Books remain an acute problem. Of twenty-six species described in the Red Data Book of Karelia (1995), the pygmy shrew (*Sorex minutissimus* Zimm), graves shrew (*Sorex isodon* Turov), brown bat (*Plecotus auritus* L.), common field mouse (*Apodemus silvaticus* Melch.), yellow-necked mouse (*Apodemus flavicolis* Melch.), striped field mouse (*Apodemus agrarius* Pall.), black rat (*Rattus rattus* L.), wood lemming (*Myopus schisticolor* Lill.), European hare, arctic fox (*Alopex lagopus* L.) and polecat are not in need of special protection. The pond bat (*Myotis dasycneme* Boie), water bat (or Daubenton's bat – *Myotis daubentoni* Kuhl), whiskered bat (*Myotis mystacinus* Kuhl), flying squirrel (*Pteromys volans* L.), European beaver, garden dormouse (*Eliomus quercinus* L.), badger, weasel (Mustela nivalis L.) and wild forest reindeer all require partial protection. The common hedgehog (*Erinaceus europaeus* L.), European mink (*Mustela lutreola* L.), wolverine, otter (*Lutra lutra* L.), Ladoga seal (*Pusa hispida ladogensis* Nordq.) and roe deer are in need of full protection. Other animals listed as rare or endangered in the Red Data book of East Fennoscandia (1998) include the large predators such as the brown bear, wolf and lynx. These species require protection in Finland whereas in Karelia they are common. Indeed, wolf hunting is permitted in Karelia all year round.

Conclusion. The long-term sustainable exploitation of game animal populations, primarily hoofed species, requires continuous management of their distribution areas, population densities, sex, age and areal structures, birth rates, mortality, etc. Observations based solely on the administrative principles will not solve the problem as seasonal migration corridors and winter sites in need of protection are located not only in different administrative units but also in different countries. Therefore international monitoring is needed. Based on a study of the seasonal migration and winter grazing sites of moose (Danilov & Markovsky, 1998) a scheme indicating a network of temporary protection areas (wildlife reserves) was made in order to restore moose populations (Fig. 51). Large predators have become an acute problem. They are protected in Finland and other EU countries but in Karelia and other parts of North European Russia their numbers need to be controlled. The sustainable exploitation and management of cervids and predatory animal populations will help to maintain the genetic diversity of these animals as well as their roles within ecosystems and their significance to human society.

3.6. Birds

3.6.1. General characteristics of bird fauna

Introduction. Owing to its geographic position and nature Karelia has long been a source of great interest to ornithologists (Neufeldt, 1970). In spite of this little is known about the species composition and distribution of birds in Karelia. In the review 'Bird fauna of Karelia' (Zimin et al., 1993) an attempt was made for the first time to summarise data concerning the composition and distribution of individual bird species. The authors of this book have analysed the relevant literature published before 1991, the archives of the Karelian Research Centre and the information collected by the Kivach Strict Reserve. They have found that available data for the bird fauna of much of Karelia is old and fragmentary. Indeed, some areas have not been studied at all. Gaps in our knowledge have been partly filled over the past few years by a large-scale inventory conducted largely under the programme entitled 'Inventory and study of biodiversity in the Republic of Karelia'. Some projects received support from the Russian Ministry of Science and Technology, the Bird Conservation Union of Russia, the Kizhi Reserve Museum and the Kenozersky National Park.

Studies on bird fauna carried out over the past decade have thrown more light on the boundaries, distribution patterns and occurrence of many birds in Karelia. New evidence for the nesting of rare species has been presented in numerous papers published in local and important journals. The Red Data Book of Karelia (1995) and the Red Data Book of East Fennoscandia (1998) have both appeared. The most valuable ornithological sites have been listed in the catalogue entitled ‘Important Bird Areas of International Value in European Russia’ (Important…2000a,b) and in the Ramsar Convention Lists of Wetlands (Wetlands …, 1998, 1999, 2000). New strictly protected areas (SPAs) have been established to conserve regional bird fauna. Information on all SPAs established up to 2000 is presented in the report ‘Strictly protected areas of Karelia’ (Hokhlova et al, 2000).

The present paper reviews the main results of bird studies conducted in Karelia over the past decade. Additional information for the review ‘Bird fauna of Karelia’ (Zimin et al., 1993) is summarised, existing evidence concerning species composition is updated and a list of Karelian birds drawn up at the end of 2000 is presented (Table 24).

Table 24

Strictly protected areas (SPA) are most vital for the protection of Karelian birds

Name of Reserve	Area (ha)
State Strict Nature Reserves	
Kivach	10 900 (+ 5 800 protection zone)
Kostomuksha	47 600
State National Parks	
Vodlozero	468 300 (130 600 in Karelia, 337 700 in the Arkhangelsk area)
Paanajärvi	104 400
State Federal Zoological Reserves	
Olonetsky	27 000
Kizhsky	50 000
State Regional Hunting Reserves	
Keretsky	21 000
Vongomsky	6 500
Shuiostrovsky	10 000
Tuloksky	10 000
Northern Priladozhye	13 200
State Regional Mire Reserves	
Nyukhcha Mire	3 500
State Regional Landscape Reserves	
Shaidomsky	29 000
Muromsky	32 600
Kuzova	3 600
Andrusovo	900
Arctic Circle	28 600
Tolvajärvi	41 900
Soroksky	73 900
West Archipelago	19 500
State Regional Mire Natural Monuments	
Vazhinsky Mire	8 500
Lebyazhye Mire	700
State Native Landscape Area	
Valaam	24 700

Characteristics of the study region and background of ornithological research. Karelia is located in north-western Russia in the north and mid-taiga subzones and borders Finland to the west. It extends 660 km from north to south and 424 km from west to east while its area amounts to 180 520 square kilometres. Forests cover over half of Karelia, water bodies make up 23%, mires about 20% and residential areas, communication facilities etc. just 1.5%. Agricultural lands account for only 1.1%. Karelia has a unique hydrological network consisting of 26 700 rivers, over 61 000 lakes including Ladoga and Onega, the largest lakes in Europe, and also the western part of the White Sea. Mires are highly diverse and together with paludified forests make up 30% of Karelian area (State report, 1998). Karelia’s bird fauna is dominated by species restricted to tree-shrub and wetland habitats. Open landscape and synantropic birds associated with human habitations are scarce.

Karelia is located on the eastern margin of the Baltic shield between 60°40' N and the Arctic Circle (66º40' N). This latitude constitutes a zone of contact between large ornitofaunistical complexes associated with European deciduous forests, European north-taiga, Siberian taiga and the Arctic zone. Thus the regional fauna is highly heterogeneous and over 40% of species occur close to their distribution boundaries (Zimin, 1988).

Both the biotope spectrum and species composition of plants and animals change gradually on moving northwards. Some broad-leaved trees such as lime, elm and common alder are still present in southern Karelia. However, in the northern part of the region the proportion of north-taiga and Arctic species rises. Rugged relief, numerous islands and coastal zones, a variety of small water bodies and river systems, and a plethora of mire types contribute to the environmental diversity of the region. The mainland portion of Karelia is relatively uniform but three provinces connected with large water bodies, namely, the White Sea province (Pribelomorye), the Lake Ladoga province

(Priladozhye) and Obonezhye, are quite unique. As environmental differences also affect bird populations the bird communities scattered throughout the region often differ considerably from one another.

All the above factors make Karelia one of the most interesting faunistic regions in North Russia (Neufeldt, 1970). However, poor roads, sparsely populated areas, extensive mires and numerous insular systems make it difficult to study the region in detail. Consequently, field work has long been restricted to preliminary studies carried out close to major highways and data on bird fauna has only occasionally been collected. It was not until the 20th century that detailed studies facilitated by the establishment of the Kandalaksha and Kivach Strict Reserves and the founding of the Karelian Research Centre RAS began. Most attempts to summarise and systematise fragmental data on regional bird fauna were made as part of a zoogeographic demarcation (Bianki,1922; Ìarvin, 1947, 1957; Neufeldt, 1958; Ivanter, 1968).

I. A. Neufeldt (1970) was the first to sum up initial data. She described the background of ornithological research in Karelia, analysed earlier information and drew up a complete list of 231 bird species.

In the 1970s–1980s population studies of representative bird species were conducted in selected areas (Zimin & Kuzmin, 1980; Zimin, 1988 et al.). This work began in Prionezhye and continued in eastern Priladozye at the Experimental Station of the Institute of Biology near Obzha. Additional studies were carried out in the Kivach Strict Reserve. Regional fauna was studied in the vicinity of Kostomuksha and in the Kizhi Skerries. Birds were counted in various types of landscapes (Danilov et al., 1977; Hokhlova, 1977; Volkov et al.,1995 et al.). An updated list of 282 bird species known in the region was presented in the review 'Bird fauna of Karelia' (Zimin et al., 1993). Five species were not included in this list due to their uncertain status.

Lack of funding for basic research in the 1990s hindered population studies. At the same time new opportunities were provided and sources of funding were found in Karelia and adjacent areas. Some territories near the Russian-Finnish border, in Zaonezhye, Priladozye, Pribelomorye and in Central Karelia were studied. Existing and proposed national parks, the Kuzova, Soroksky, Andrusovo and West Archipelago Landscape Reserves and other protected areas were investigated (Sazonov,1997; Sazonov & Medvedev, 1997, 1999; Zimin et al., 1998a; Sazonov et al.,1994, 1998; Hokhlova, 1998; Hokhlova & Artemyev, 1999; Hokhlova et al., 2000b et al.). Also studied were the adjacent parts of the Arkangelsk Oblast near the Vodlozerskyo and Kenozersky National Parks and in the vicinity of Lake Lacha (Sazonov, 1995; Hokhlova et al., 1998, 1999 et al.). Ornithological monitoring is now in progress in the Kivach Strict Reserve and in the Olonets and Kizhi Federal Reserves. New information on spring bird migration in Priladozhye (Zimin et al., 1997, 1998 á) and the first evidence for autumn migration in Zaonezhye were obtained (Hokhlova et al., 1999 á). Up-to-date information on birds in the Valaam Archipelago was collected (Mikhaleva & Birina,1997 et al.). The review paper 'Birds of the Kola-White Sea region' (Bianki et al.,1993) was published and several other papers dealing in part with Karelia appeared. These studies provided a large body of new data on the populations, distribution patterns and biology of bird species in Karelia.

Results. The list of Karelian birds made up in the year 2000 consists of 291 species (Appendix). Of these 210 are nesting species (Grey Partridge *Perdix perdix* no longer breed in Karelia), 21 species are transitory (three of them are assumed to nest occasionally) and 56 species are occasionally observed (9 of which probably nest occasionally). The scientific names of bird species in the text and in the table are given in accordance with 'The EBCC Atlas of European Breeding Birds' (1997).

Added to the earlier list (Zimin et al., 1993) are the Storm Petrel *Hydrobates pelagicus*, Gannet *Morus bassana,* Pallid Harrier *Circus macrourus*, Middle Spotted Woodpecker *Dendrocopos medius*, Calandra Lark *Melanocorypha calandra*, Tawny Pipit *Anthus campestris*, Rock Pipit *A. petrosus*, Lanceolated Warbler *Locustella lanceolata* and Arctic Redpoll *Carduelis hornemanni*. More light was shed on the nesting patterns of Steller's Eider *Polysticta stelleri,* King Eider *Somateria spectabilis*, Spotted Redshank *Tringa erythropus*, and Red-Flanked Bluetail *Tarsiger cyanurus* etc. and the migration of the White-billed Diver *Gavia adamsii*, Glaucous Gull *Larus hyperboreus*, Whater Rail *Rallus aquaticus*, Short-toed Eagle *Circaetus gallicus*, Montagu's Harrier *Circus pygargus* and Redshank *Tringa totanus (*Zimin et al., 1997 b,c; 1998c; Kokhanov, 1998, 1999; Mikhaleva & Birina, 1997).

Of special interest is evidence concerning the distribution and population dynamics of species occurring close to their distribution boundaries which contribute greatly to regional fauna in Karelia (Lapshin, 1997; Zimin et al.,1997 à; Hokhlova et al.,1999 à, b; Artemyev & Hokhlova, 2000; Hokhlova & Artemyev, 2000 à,b et al.). This data is used to more precisely identify the nesting sites and regular nesting zones of the White Stork *Ciconia ciconia*, White-Backed Woodpecker *Dendrocopos leucotos*, Black Tern *Chlidonias niger,* Coot *Fulica atra*, Hawfinch *Coccothraustes coccothraustes*, Red-throated Diver *Gavia stellata*, Red-necked Grebe *Podiceps griseigena*, and Whooper Swan *Cygnus cygnus,* etc. Long-term observation was conducted in some parts of the region to trace shifts in the boundaries of distribution areas and to cast more light on the population dynamics of the Great Crested Grebe *Podiceps cristatus*, Little Gull *Larus minutus*, Black-headed Gull *Larus ridibundus*, Honey Buzzard *Pernis apivorus*, Buzzard *Buteo buteo* etc. Important new evidence was also collected concerning the occurrence and breeding of rare species including the Pochard *Aythya ferina*, Oystercatcher *Haematopus ostralegus*, Arctic Tern *Sterna paradisaea* Pontopp., Little Bunting *Emberiza pusilla*, Stonechat *Saxicola torquata,* Quail *Coturnix coturnix*, Greenfinch *Carduelis chloris*, Blue Tit *Parus caeruleus*, Booted Warbler *Hippolais caligata* and Arctic Warbler *Phylloscopus borealis,* etc. in uncommon nesting zones.

Rare and poorly represented species. Many rare and poorly represented bird species are in need of protection. Some birds listed in the Red Data Book of Russia (2000), e. g. the Black-throated Diver *Gavia àrctica*, Osprey

Pandion haliaetus and Curlew *Numenius arquata,* are still quite common here. The Red Data Book of Karelia, published in 1995 contains data on 47 bird species (Appendix, bold type) as well as reviews of information on individual species collected before 1993.

Additional data concerning the distribution of rare species, in particular certain large predatory birds included in international lists of protected species, has been obtained over the past few years (Sazonov, 1995; Zimin et al., 1998c; Artemyev & Hokhlova, 1999 et al.). Our studies show that the distribution areas and populations of some birds have changed considerably in the past decade and, therefore, require more attention. Listed in the Red Books for adjacent parts of Russia and East Fennoscandia (1998) are 50 Karelian bird species. In a revised version of the Red Data Book of Russia reference is made to some populations whose numbers have been falling throughout the region. Detailed in the Red Data Book of Russia (1985) were 11 Karelian bird species. In a new edition of the Red Data Book of Russia 25 species are described with 14 more species listed in the Supplement as birds in need of protected status (Red Data Book of Russia, legal acts, 2000). Thus, the lists of Karelian protected birds need to be revised and reviews extended.

Zoogeographic demarcation. Based on new and more complete information on the species composition and regional distribution of birds, attempts to more accurately demarcate Karelia zoogeographically can be made. Until now demarcation has consisted of subdividing Karelia into the South Karelian, Mid-Karelian and North Karelian zoogeographic subprovinces. All scientists agree, however, that the White Sea region is faunistically quite different from the other zoogeographic provinces.

Our analytical data reveals a specific pattern displayed by the coastal and insular bird fauna in the White Sea region (Bianki et al., 1993; Zimin, 1998; Kokhanov, 1999; Sazonov & Medvedev, 1999; Hokhlova & Artemyev, 1999 et al.). Thus, Pribelomorye can be regarded as a zoogeographic province in the Kola-White Sea region (Bianki et al.,1993).

Subdivision of the mainland portion of Karelia into three latitudinal zones seems to be appropriate. Difference in the species composition of birds at the western and eastern boundaries of each subprovince is relatively small. Indeed, the only significant difference is the occurrence of the Ring Quzel *Turdus torquatus* in the Lake Paanajärvi area. At the same time, the southern and northern boundaries of the Middle Karelian transitional subprovince presently drawn along latitudes 62° and 63°30' N respectively (Ivanter, 1975) should be corrected in accordance with new evidence concerning bird distribution areas which indicates that the above range of latitudes only reflects the situation in the central part of the region. In eastern Karelia the southern boundaries of many northern birds extend much farther south of 62 ° N. In western Karelia the northern boundaries of southern species stretch north of 63°30' N. However, available data on the present bird distribution pattern in Middle Karelia is too scanty to delineate this transitional subprovince more precisely.

Differences in the species composition of birds in each zone usually result from permanent changes in local environments caused by considerable anthropogenic transformation to the landscapes. At the same time there are areas in Karelia that owe their faunistic diversity to characteristics of the local environment. For example, the skerries and islands in northern Priladozye may be identified as highly valuable ecological zones.

In the islands located in the north-eastern part of Lake Ladoga semi-marine conditions prevail. Common species occur together with some nesting marine birds such as the Velvet Scoter *Melanitta fusca*, Long-tailed Duck *Clangula hyemalis*, Eider *Somateria molissima*, Arctic Tern, Turnstone *Arenaria interpres*, Oystercatcher and a colony of Caspian Tern *Sterna caspia* (Medvedev, Sazonov, 1994; Pakarinen & Siikavirta, 1993; Birina, 1994; Mikhaleva & Birina, 1997; Lapshin, 2000).

Zaonezhye is remarkable for the prolificacy and diversity of its bird populations. This a meeting point for southern and northern species. The Whooper Swan, Arctic Tern and Oystercatcher are found here while nesting birds include the Little Gull, Great Crested Grebe, Bittern *Botaurus stellaris*, Spotted Crake *Porzana porzana*, Coot, Thrush Nightingale *Luscinia luscinia*, Greenfinch *Carduelis chloris*, Blue Tit, Hawfinch, Goldfinch *Carduelis carduelis* and many other southern species (Hokhlova, 1998, Hokhlova & Artemyev, 2000c; Hokhlova et al., 2000b).

Important Birds Areas (IBA). Owing to its nature and geographic position Karelia is an important region for many North European bird populations. Local environments are conducive to large-scale breeding of wetland and taiga species. Birds that migrate along the White Sea-Baltic Sea corridor gather here. Although Karelia is a small northern region its bird fauna is as prolific and specifically diverse as that of large regions lying further south, e.g. the Moscow Province (Important …, 2000a).

A survey of IBAs of regional, federal and international value began in Karelia in 1997 and is still in progress. Most of the nine localities of European and global significance selected and listed in the Catalogue 'Important Bird Areas of international significance in European Russia' (Important …, 2000a,b) are sites at which large numbers of wetland birds nest or congregate during migration. These are 1) the Olonets Plain; 2) reed-covered shallow-water zones near the eastern shore of Lake Ladoga; 3) the Valaam Archipelago; 4) Zaonezhye skerries; 5) some lakes in northern Karelia; 6) Onega Bay area of the White Sea (partly in the Arkhangelsk Province); 7) Kandalaksha Bay area of the White Sea (partly in the Murmansk Oblast); 8) the Lake Vodlozero area inhabited by the largest group of rare birds of prey; and 9) the Kivach Strict Reserve with its typical Karelian coniferous taiga bird complex. Two more IBAs of international significance, namely the Lake Kenozero area (Kenozersky National Park and its environs together with the Plesetsk and Kargopol districts) and Lake Lacha (Kargopol district), were selected from Arkhangelsk Province adjoining south-eastern Karelia.

The Kuzova Islands and Kandalaksha Bay were included in the Ramsar Convention List of Wetlands of International Significance (1998), three more localities were added to the Ramsar Convention Perspective List (2000) and some other territories were proposed for a second version of the List (Kuznetsov & Hokhlova, 2000).

At the same time, *Karelia is expected to contain a much greater number of ornithologically valuable territories than is presently recognised.* Preliminary information on less thoroughly studied localities elsewhere in Karelia is yet to be corroborated. A list of IBAs of local value is to be made up. Therefore, the inventory process needs to be continued in Karelia in the future.

The impact of human activities. Analysis has revealed important changes in the bird fauna of Karelia over the past few decade. The most important single cause of this has been the increasing transformation of landscapes by commercial activities. Taiga nature has been destroyed by deforestation, forest reclamation, the pollution and eutrophication of water bodies, the use of herbicides, forest fires, irresponsible tourism, the construction of communication lines, etc. However, the greatest detrimental effect on Karelian native communities results from the large-scale felling of primeval forests which are then succeeded by secondary stands.

Primeval forests in Karelia consist of various types of pine and spruce stands. According to official statistical data (State report …, 1998) pine and spruce stands cover 89% of Karelia's forested area. However, all of these have been damaged by felling and most exist in the form of managed stands with profoundly altered age structures and relatively high proportions of deciduous species. Young stands (39%) and medium-aged forests (21.2%) predominate. Relatively large fragments of only slightly transformed old-growth forests have survived mainly near to the Finnish-Russian border, in the Pudozh and Kondopoga districts (Kivach Strict Reserve) and along the White Sea coast.

The bird populations of undisturbed north taiga is highly stable but its species composition is relatively poor and total numbers of birds are small (100–200 pairs/km2). Secondary stands and their fauna have certain characteristics of their own which depend on the forest management methods used. For instance, the large-scale intensive management of forests in Finland has impoverished its native communities and profoundly affected the habitats of many forest birds. Consequently, some species listed as being very rare in the Red Data Books of Finland and Eastern Fennoscandia (1998), e.g. the Great Grey Owl *Strix nebulosa*, Pygmy Owl *Glaucidium passerinum*, White-Backed Woodpecker and Great Grey Shrike *Lanius excubitor* etc., are not rare in Karelia. Since felling technology on the Russian side of the border differs from that employed in Finland, Karelian transformed forests are characterised by complex age structures and species composition of vegetation, mosaic and fragmented biotopes, decaying wood and well-developed undergrowth. Their bird populations are highly diversity and numerous (700–800 pairs/km? (Hokhlova, 1977, 1998; Volkov et al., 1990; 1995). Indigenous fauna is enriched by species associated with deciduous forests. The anthropogenic transformation of landscapes is also associated with an increase in the numbers and population densities of southern species (Zimin, 1988).

These processes are especially pronounced in the Mid-Karelian zoogeographic subprovince. Over the past 30 years the nesting fauna of Zaonezhye (Hokhlova,1977, 1998 à; Hokhlova & Artemyev, 1996) has grown to include the Thrush Nightingale, Blyth's Reed Warbler *Acrocephalus dumetorum,* Marsh Warbler *A. palustris*, Blackcap *Sylvia atricapilla*, Wood Warbler *Phylloscopus sibilatrix*, Greenish Warbler *Ph. trochiloides*, Blackbird *Turdus merula*, Hawfinch and Little Gull *Larus minutus.* The populations of Great Crested Grebe, Honey Buzzard and Black-headed Gull have markedly increased. Many southern species, e.g. the Corncrake *Crex crex*, Icterine Warbler *Hippolais icterina*, Common Rosefinch *Carpodacus erythrinus*, Garden Warbler *Sylvia borin*, Great Tit *Parus major* etc., are far more common and numerous than would be expected at these latitudes. At the same time, indigenous taiga birds adapted to northern environments such as the Capercaillie *Tetrao urogallus*, Hazel Grouse *Bonasa bonasia*, Three-toed Woodpecker *Picoides tridactylus* etc., are less well represented.

To sum up, as primeval forests are being transformed the species diversity and prolificacy of forest bird species are increasing in Karelia in contrast to the majority of Europe. It should be noted that the largest contribution is made by unstable peripheral populations of species which are intrinsically poorly adaptable to northern conditions. Thus, the replacement of indigenous taiga bird communities by more diverse ones is accompanied by a decline in the hardiness Karelian bird cenoses.

Strictly protected areas (SPAs). The conservation of native bird habitats is promoted by a network of strictly protected areas that covers 5.5% of Karelia (Hokhlova et al., 2000 à). Various forms of prohibition or restriction of wildlife management activities such as amelioration, clear felling, fishing, licensed hunting etc., has greatly reduced the impact of human activities on ecosystems in protected areas even though full protection is not really ensured. These steps taken are important for the maintenance of the breeding potential and species diversity of Karelian fauna. SPAs provide shelter for the largest groups of protected migrating birds known in the region. Some species such as the Caspian Tern, White-tailed Eagle *Haliaeetus albicilla*, Osprey, Golden Eagle *Aquila chrysaetos*, Peregrine *Falco peregrinus* and Ring Ouzel are known to nest in Karelia.

Twenty-three SPAs are considered vital for the protection of Karelian bird fauna (Table 24). As a result of reassessment some of these, primarily large federal reserves such as the Kivach and Kostomuksha Strict Reserves, the Paanajärvi and Vodlozero National Parks, and the Olonetsky and Kizsky Federal Zoological Reserves, will be included in the list of Important Birds Areas (IBA) of Karelian and Federal value.

Appendix

LIST OF KARELIAN BIRDS

Nn	I	II	III				IV
			N	W	T	A	Source of information
	Gaviiformes						
1.	**Red-throated Diver**	***Gavia stellata*** (Pontopp.)	++	–	++	–	
2.	**White-billed Diver**	***G. adamsii*** (G.R.Gray)	–	–	–	+	Bianki et al.,1993
3.	Black-throated Diver	*G. arctica* (L.)	+++	–	+++	–	
	Podicipitiformes						
4.	Little Grebe	*Tachybaptus ruficollis* (Pall.)	–	–	–	+	Noskov et al., 1981
5.	Black-necked Grebe	*Podiceps nigricollis* Gh.L.*Brehm*	–	–	–	+	Shibanov, 1927 Noskov et al., 1981
6.	Slavonian Grebe	*P. auritus* (L.)	+	–	–	–	
7.	Red-necked Grebe	*P. grisegena* (Bodd.)	++	–	++	–	
8.	Great Crested Grebe	*P. cristatus* (L.)	++	–	++	–	
	Procellariiformes						
9.	Storm Petrel	*Hydrobates pelagicus* (L.)	–	–	–	+	Bianki et al.,1993
10.	Gannet	*Morus bassanus* (L.)	–	–	–	+	Bianki et al.,1993
	Pelicaniformes						
11.	White Pelican	*Pelecanus onocrotalus* L.	–	–	–	+	Koskimies,1979
12.	**Cormorant**	***Phalacrocorax carbo*** (L.)	+	+	+	–	
	Ciconiiformes						
13.	**Bittern**	***Botaurus stellaris*** (L.)	(+)	–	–	+	
14.	Great White Egret	*Egretta alba* (L.)	–	–	–	+	Zimin et al., 1993
15.	Grey Heron	*Ardea cinerea* L.	–	–	–	+	
16.	Spoonbill	*Platalea leucorodia* L.	–	–	–	+	Vesanen, 1929 (after Neufeldt, 1970)
17.	**White Stork**	***Ciconia ciconia*** (L.)	+	–	–	+	
18.	**Black Stork**	***C. nigra*** (L.)	–	–	–	+	Zimin et al., 1993
	Anseriformes						
19.	Mute Swan	*Cygnus olor* (Gm.)	–	–	–	+	Vesanen, 1929 (afer Neufeldt, 1970)
20.	Whooper Swan	***C. cygnus*** (L.)	++	–	+++	–	
21.	**Bewick's Swan**	***C. columbianus bewickii Yarr.***	–	–	++	–	
22.	Greylag	*Anser anser* (L.)	(+)	–	+	–	
23.	Whitefront	*A. albifrons* (Scop.)	–	–	+++	–	
24.	**Lesser Whitefront**	***A. erythropus*** (L.)	–	–	+	–	
25.	**Bean Goose**	***A. fabalis*** (Lath.)	++	–	+++	–	
26.	**Canada Goose**	***Branta canadensis*** (L.)	+	–	+	+	
27.	**Barnacle Goose**	***B. leucopsis*** (Bechst.)	–	–	+	–	
28.	**Brent Goose**	***B. bernicla*** (L.)	–	–	++	–	
29.	Ruddy Shelduck	*Tadorna ferruginea* (Pall.)	–	–	–	+	Koskimies, 1979
30.	Shelduck	*T. tadorna* (L.)	(+)	–	–	+	Cherenkov & Semashko, 1990
31.	Mallard	*Anas platyrhynchos* L.	+++	++	+++	–	
32.	Teal	*A. crecca* L.	+++	+	+++	–	
33.	Gadwall	*A. strepera* L.	+	–	+	–	Koskimies, 1979
34.	Wigeon	*A. penelope* L.	+++	–	+++	–	
35.	Pintail	*A. acuta* L.	++	–	++	–	
36.	Garganey	*A. querquedula* L.	+	–	+	–	
37.	Shoveler	*A. clypeata* L.	+	–	+	–	
38.	**Steller's Eider**	**Polysticta stelleri** (Pall.)	+	–	–	+	Kokhanov, 1998
39.	**Eider**	***Somateria molissima*** (L.)	+++	+++	++	–	
40.	King Eider	*S. spectabilis* (L.)	+	–	–	+	Kokhanov, 1999
41.	Pochard	*Aythya ferina* (L.)	+	–	+	–	
42.	Tufted Duck	*A. fuligula* (L.)	+++	–	+++	–	
43.	Scaup	*A. marila* (L.)	++	–	++	–	
44.	Mandarin	*Aix galericulata* (L.)	–	–	–	+	Zimin et al., 1993
45.	**Velvet Scoter**	***Melanitta fusca*** (L.)	++	–	++	–	
46.	Common Scoter	*M. nigra* (L.)	+	–	+++	–	
47.	Long-tailed Duck	*Clangula hyemalis* (L.)	+	+	+++	–	
48.	Goldeneye	*Bucephala clangula* (L.)	+++	+	+++	–	
49.	*Barrow's Goldeneye*	*B. islandica* (Gm.)	–	–	–	+	Borshchevsky,1999
50.	**Smew**	***Mergus albellus*** L.	+	–	+	–	
51.	Red-breasted Merganser	*M. serrator* L.	+++	+	+++	–	
52.	Goosander	*M. merganser* L.	++	+	++	–	
	Falconiformes						
53.	**Osprey**	***Pandion haliaetus*** (L.)	++	–	+	–	
54.	Honey Buzzard	*Pernis apivorus* (L.)	++	–	++	–	
55.	**Black Kite**	***Milvus migrans*** (Bodd.)	+	–	+	–	
56.	**White-tailed Eagle**	***Haliaeetus albicilla*** (L.)	+	+	+	–	
57.	Goshawk	*Accipiter gentilis* (L.)	++	++	++	–	
58.	Sparrowhawk	*A. nisus* (L.)	+++	++	+++	–	
59.	Rough-Legged Buzzard	*Buteo laqopus* (Pontopp.)	+	+	++	–	
60.	Buzzard	*B. buteo* (L.)	++	–	++	–	

Nn	I	II	III				IV
			N	W	T	A	Source of information
61.	**Spotted Eagle**	***Aquila clanga Pall.***	+	–	+	–	
62.	Lesser Spotted Eagle	*A. pomarina Ch. L. Brehm*	–	–	–	+	
63.	**Golden Eagle**	***A. chrysaetus*** (L.)	+	+	+	–	
64.	Egyptian Vulture	*Neophron percnopterus* (L.)	–	–	–	+	Mericallio, 1958
65.	Griffon Vulture	*Gyps fulvus* (Halb.)	–	–	–	+	Koskimies, 1979
66.	**Short-toed Eagle**	***Circaetus gallicus (***Gm.)	–	–	–	+	
67.	Hen Harrier	*Circus cyaneus* (L.)	++	–	++	–	
68.	Pallid Harrier	*C. macrourus* (Gm.)	–	–	–	+	Zimin et al., 1997 b
69.	Montagu’s Harrier	*C. pygargus* (L.)	(+)	–		+	Zimin et al., 1997 c; State Report.,1998
70.	Marsh Harrier	*C. aeruginosus* (L.)	+	–	+	–	
71.	**Kestrel**	***Falco tinnunculus*** L.	+	–	+	–	
72.	**Merlin**	***F. columbarius*** L.	++	+	++	–	
73.	Red-footed Falcon	*F. vespertinus* L.	+	–	+	–	
74.	Hobby	*F. subbuteo* L.	+++	–	+++	–	
75.	**Gyrfalcon**	***Falco rusticolus*** L.	–	–	(+)	+	Bianki et al.,1993; Zimin et al.,1993
76.	**Peregrine**	***Falco peregrinus*** **Tunst.**	+	–	+	–	
	Galliformes						
77.	**Grey Partridge**	***Perdix perdix*** (L.)	/+/	/+/	–	–	
78.	**Quail**	**Coturnix coturnix** (L.)	+	–	–	+	
79.	Pheasant	*Phasianus colchicus* L.	–	–	–	+	Zimin et al.,1993
80.	Ptarmigan	*Lagopus mutus* (Mont.)	–	–	–	+	
81.	Willow Grouse	*L. lagopus* (L.)	++	++	–	–	
82.	Capercaillie	*Tetrao urogallus* L.	++	++	–	–	
83.	Black Grouse	*T. tetrix* (L.)	+++	+++	–	–	
84.	Hazel Grouse	*Tetrastes bonasia* (L.)	+++	++	–	–	
	Gruiformes						
85.	**Corncrake**	***Crex crex*** **(L.)**	++	–	++	–	
86.	Spotted Crake	*Porzana porzana* (L.)	+	–	–	–	
87.	Little Crake	*P. parva* (Scop.)	(+)	–	–	+	Zimin et al.,1993
88.	Water Rail	*Rallus aquaticus* L.	–	–	–	+	Mikhaleva & Birina, 1997
89.	Moorhen	*Gallinula chloropus* (L.)	(+)	–	–	+	Koskimies, 1979
90.	Coot	*Fulica atra* L	+	–	–	–	
91.	**Crane**	***Grus grus*** (L.)	++	–	++	–	
	Charadriiformes						
92.	Grey Plover	*Pluvialis squatarola* (L.)	–	–	+	–	
93.	Golden Plover	*Pl. apricaria* (L.)	++	–	+++	–	
94.	Ringed Plover	*Charadrius hiaticula* L	++	–	++	–	
95.	Little Ringed Plover	*Ch. dubius Scop.*	++	–	++	–	
96.	Dotterel	*Ch. morinellus* L.	–	–	+	–	
97.	Lapwing	*Vanellus vanellus* (L.)	+++	–	+++	–	
98.	Oystercatcher	*Haematopus ostralegus* L.	+++	–	++	–	
99.	Green Sandpiper	*Tringa ochropus* L.	+++	–	++	–	
100.	Wood Sandpiper	*T. glareola* L.	++	–	+++	–	
101.	Greenshank	*T. nebularia* (Gunn.)	++	–	++	–	
102.	Redshank	*T. totanus* L.	+	–	+	–	
103.	Spotted Redshank	*T. erythropus* (Pall.)	+	–	+	–	Kokhanov, 1999
104.	Marsh Sandpiper	*T. stagnatilis* (Bechst.)	–	–	–	+	
105.	Common Sandpiper	*Actitis hypoleucos* (L.)	+++	–	+++	–	
106.	Terek Sandpiper	*Xenus cinereus* (Guld.)	+	–	+	–	
107.	Red-necked Phalarope	*Phalaropus lobatus* L.	+	–	++	–	
108.	Turnstone	*Arenaria interpres* (L.)	++	–	++	–	
109.	Ruff	*Philomachus pugnax* (L.)	+	–	++	–	
110.	Little Stint	*Calidris minuta* (Leisl.)	–	–	+	–	
111.	Temminck’s Stint	*C. temminckii* (Leisl.)	+	–	+	–	
112.	Curlew Sandpiper	*C. ferruginea* (Pontopp.)	–	–	++	–	
113.	Dunlin	*C. alpina* (L.)	–	–	+++	–	
114.	Purple Sandpiper	*C. maritima* (Brünn.)	–	–	–	+	
115.	Sanderling	*C. alba* (Pall.)	–	–	+	–	
116.	Knot	*C. canutus* (L.)	–	–	+	–	
117.	Broad-billed Sandpiper	*Limicola falcinellus* (Pontopp.)	(+)	–	+	–	
118.	Jack Snipe	*Lymnocryptes minimus* (Brunn.)	+	–	++	–	
119.	**Great Snipe**	***Gallinago media*** **(Lath.)**	+	–	++	–	
120.	Snipe	*G. gallinago* (L.)	+++	–	+++	–	
121.	Woodcock	*Scolopax rusticola* L.	+++	–	+++	–	
122.	Curlew	*Numenius arquata* (L.)	++	–	++	–	
123.	Whimbrel	*N. phaeopus* (L.)	++	–	++	–	
124.	Black-tailed Godwit	*Limosa limosa* (L.)	(+)	–	–	+	
125.	**Bar-tailed Godwit**	***L. lapponica*** **(L.)**	(+)	–	+	–	
126.	Pomarine Skua	*Stercorarius pomarinus* (Temm.)	–	–	–	+	Bianki et al.,1993
127.	Arctic Skua	*St. parasiticus* (L.)	+	–	+	–	

Nn	I	II	III				IV
			N	W	T	A	Source of information
128.	Long-tailed Skua	*St. longicaudus* Vieill.	–	–	+	–	Noskov et al., 1991; Bianki et al.,1993
129.	Common Gull	*Larus canus* L.	+++	+	+++	–	
130.	Herring Gull	*L. argentatus* Pontopp.	++	+	++	–	
131.	**Lesser Blackback**	***L. fuscus* L.**	++	–	++	–	
132.	Great Blackback	*L. marinus* L.	++	–	++	–	
133.	Glaucous Gull	*L. hyperboreus* Gunn.	–	+	–	+	Kokhanov, 1999
134.	Black-headed Gull	*L. ridibundus* L.	+++	–	+++	–	
135.	Little Gull	*L. minutus* Pall.	++	–	++	–	
136.	Kittiwake	*Rissa tridactyla* (L.)	–	–	+	–	
137.	Black Tern	*Chlidonias niger* (L.)	(+)	–	–	+	
138.	Common Tern	*Sterna hirundo* L.	+++	–	+++	–	
139.	Arctic Tern	*St. paradisaea* Pontopp.	+++	–	+++	–	
140.	Little Tern	*St. albifrons* Pall.	(+)	–	–	+	Kokhanov, 1987; Zimin et al., 1993
141.	**Caspian Tern**	***St. caspia* (Pall.)**	+	–	–	–	
142.	Black Guillemot	*Cepphus grylle* (L.)	++	–	–	–	
143.	Guillemot	*Uria aalge* (Pontopp.)	–	–	–	+	Bianki et al., 1993
144.	Brünnich's Guillemot	*U. lomvia* (L.)	–	–	–	+	Bianki et al., 1993
145.	Little Auk	*Alle alle* (L.)	–	+	+	–	
146.	Razorbilll	*Alca torda* (L.)	++	+	++	–	
147.	Puffin	*Fratercula arctica* (L.)	+	–	+	–	Zimin et al., 1993
	Columbiformes						
148.	Rock Dove	*Columba livia* L.	+++	+++	–	–	
149.	Stock Dove	*C. oenas* L.	+	–	+	–	
150.	Wood Pigeon	*C. palumbus* L.	++	–	++	–	
151.	Turtle Dove	*Streptopelia turtur* (L.)	+	–	+	–	
152.	Collared Dove	*S. decaocto* (Frivald.)	+	–	–	–	
	Cuculiformes						
153.	Cuckoo	*Cuculus canorus* L.	+++	–	+++	–	
154.	Oriental Cuckoo	*C. saturatus* Blyth.	–	–	–	+	
	Strigiformes						
155.	**Eagle Owl**	***Bubo bubo* (L.)**	+	+	+	–	
156.	**Snowy Owl**	***Nyctea scandiaca* (L.)**	–	+	+	–	
157.	Hawk Owl	*Surnia ulula* (L.)	++	+	++	–	
158.	**Pygmy Owl**	***Glaucidium passerinum* (L.)**	++	++	++	–	
159.	**Great Grey Owl**	***Strix nebulosa* J.R.Forst.**	+	+	+	–	
160.	Tawny Owl	*S. aluco* L.	+	(+)	+	–	
161.	Ural Owl	*S. uralensis* Pall.	++	++	++	–	
162.	Long-eared Owl	*Asio otus* (L.)	+	–	+		
163.	Short- eared Owl	*A. flammeus* (Pontopp.)	++	–	++	–	
164.	Tengmalm's Owl	*Aegolius funereus* (L.)	++	++	++	–	
	Caprimulgiformes						
165.	Nightjar	*Caprimulgus europaeus (*L.)	++	–	+	–	
	Apodiformes						
166.	Swift	*Apus apus* (L.)	+++	–	+++	–	
	Coraciiformes						
167.	Kingfisher	*Alcedo atthis* (L.)	–	–	–	+	
168.	Roller	*Coracias garrulus* L.	–	–	–	+	
169.	Hoopoe	*Upupa epops* L.	–	–	–	+	
	Piciformes						
170.	Wryneck	*Jynx torquilla* L.	++	–	++	–	
171.	Black Woodpecker	*Dryocopus martius* (L.)	++	++	++	–	
172.	Green Woodpecker	*Picus viridis* L.	–	–	–	+	Koskimies, 1979
173.	Grey-headed Woodpecker	*P. canus Gm.*	+	+	+	–	
174.	Great Spotted Woodpecker	*Dendrocopos major* (L.)	+++	+++	+++	–	
175.	White-Backed Woodpecker	***D. leucotos (*Bechst.)**	++	++	++	–	
176.	Middle Spotted Woodpecker	*D. medius* (L.)	–	–	–	–	
177.	Lesser Spotted Woodpecker	*D. minor* (L.)	+	+	+	–	
178.	Three-toed Woodpecker	*Picoides tridactylus* (L.)	++	++	++	–	
	Passeriformes						
179.	Calandra Lark	*Melanocorypha calandra* (L.)	–	–	–	+	State Report,1998
180.	**Woodlark**	***Lullula arborea* (L.)**	+	–	+	–	
181.	Skylark	*Alauda arvensis* L.	+++	–	+++	–	
182.	**Shore Lark**	***Eremophila alpestris* (L.)**	–	–	++	–	
183.	Sand Martin	*Riparia riparia* (L.)	++	–	++	–	
184.	Swallow	*Hirundo rustica* L.	+++	–	+++	–	
185.	House Martin	*Delichon urbica* (L.)	+++	–	+++	–	
186.	Yellow Wagtail	*Motacilla flava* L.	++	–	+++	–	
187.	Citrine Wagtail	*M. citreola Pall.*	+	–	–	+	Zimin et al.,1993
188.	White Wagtail	*M. alba* L.	+++	–	+++	–	
189.	Tawny Pipit	*Anthus campestris* (L.)	–	–	–	+	Bianki et al., 1993
190.	Tree Pipit	A. *trivialis* (L.)	+++	–	+++	–	

Nn	I	II	III				IV
			N	W	T	A	Source of information
191.	Meadow Pipit	*A. pratensis* (L.)	++	–	++	–	
192.	Red-throated Pipit	*A. cervinus* (Pall.)	–	–	+	–	
193.	Rock Pipit	*A. petrosus* (L.)	+	–	–	–	Zimin et al., 1998c
194.	Red-backed Shrike	*Lanius collurio* L.	++	–	++	–	
195.	Lesser Grey Shrike	*L. minor Gm.*	–	–	–	+	Leivo, 1950
196.	**Great Grey Shrike**	***L. excubitor*** **L.**	+	(+)	+	–	
197.	Waxwing	*Bombycilla garrulus* (L.)	+	++	++	–	
198.	**Dipper**	***Cinclus cinclus*** **(L.)**	+	+	+	–	
199.	Wren	*Troglodytes troglodytes* (L.)	++	–	++	–	
200.	Dunnock	*Prunella modularis* (L.)	++	–	++	–	
201.	Robin	*Erithacus rubecula* (L.)	+++	(+)	+++	–	
202.	Thrush Nightingale	*Luscinia luscinia* (L.)	+	–	+	–	
203.	Bluethroat	*L. svecica* (L.)	+	–	++	–	
204.	Red-Flanked Bluetail	*Tarsiger cyanurus* (Pall.)	+	–	–	+	State Report, 2000
205.	Black Redstart	*Phoenicurus ochruros* (L.)	–	–	–	+	Zimin & Ivanter, 1986; Kokhanov, 1999
206.	**Redstart**	***Ph. phoenicurus*** **(L.)**	++	–	++	–	
207.	Whinchat	*Saxicola rubetra* (L.)	+++	–	+++	–	
208.	Stonechat	*S. torquata* (L.)	+	–	–	+	
209.	Wheatear	*Oenanthe oenanthe* (L.)	+++	–	++	–	
210.	Blackbird	*Turdus merula* L.	++	+	++	–	
211.	**Ring Ouzel**	***T. torquatus*** **L.**	+	–	+	–	
212.	Fieldfare	*T. pilaris* L.	+++	+	+++	–	
213.	Redwing	*T. iliacus* L.	+++	–	+++	–	
214.	Song Thrush	*T. philomelos* G.L.Brehm.	+++	–	+++	–	
215.	Mistle Thrush	*T. viscivorus* L.	+	–	+	–	
216.	River Warbler	*Locustella fluviatilis* (Wolf)	(+)	–	–	+	
217.	Grasshopper Warbler	*L. naevia* (Bodd.)	+	–	+	–	
218.	Lanceolated Warbler	*L. lanceolata* (Temm.)	–	–	–	+	
219.	Sedge Warbler	*Acrocephalus schoenobaenus* (L.)	+++	–	+++	–	
220.	Blyth's Reed Warbler	*A. dumetorum* (Blyth)	+++	–	+++	–	
221.	Marsh Warbler	*A. palustris* (Bechst.)	++	–	++	–	
222.	Reed Warbler	*A. scirpaceus* (Herm.)	+	–	+	–	
223.	Great Reed Warbler	*A. arundinaceus* (L.)	+	–	–	–	
224.	Icterine Warbler	*Hippolais icterina* (Vieill.)	++	–	+	–	
225.	Booted Warbler	*H. caligata* (Licht.)	+	–	–	–	State Report, 2000
226.	Barred Warbler	*Sylvia nisoria* (Bechst.)	+	–	+	–	
227.	Garden Warbler	*S. borin* (Bodd.)	+++	–	+++	–	
228.	Blackcap	*S. atricapilla* (L.)	+	–	+	–	
229.	Whitethroat	*S. communis* Lath.	++	–	++	–	
230.	Lesser Whitethroat	*S. curruca* (L.)	++	–	++	–	
231.	Willow Warbler	*Phylloscopus trochilus* (L.)	+++	–	+++	–	
232.	Chiffchaff	*Ph. collybita* (Vieill.)	++	–	++	–	
233.	Wood Warbler	*Ph. sibilatrix* (Bechst.)	++	–	++	–	
234.	Yellow-browed Warbler	*Ph. inornatus* (Blyth)	–	–	–	+	
235.	Pallas's Warbler	*Ph. proregulus* (Pall.)	–	–	–	+	
236.	Arctic Warbler	*Ph. borealis* (Blas.)	+	–	+	–	
237.	Greenish Warbler	*Ph. trochiloides* (Sund.)	++	–	++	–	
238.	Goldcrest	*Regulus regulus* (L.)	+++	+	+++	–	
239.	Spotted Flycatcher	*Muscicapa striata* (Pall.)	+++	–	+++	–	
240.	Pied Flycatcher	*Ficedula hypoleuca* (Pall.)	++	–	++	–	
241.	Red-breasted Flycatcher	*F. parva* (Bechst.)	+	–	+	–	
242.	Long-tailed Tit	*Aegithalos caudatus* (L.)	++	+	+++	–	
243.	Marsh Tit	*Parus palustris* L.	–	–	–	+	Zimin et al.,1993
244.	Willow Tit	*P. montanus* Bald.	+++	+++	+++	–	
245.	Siberian Tit	*P. cinctus* Bodd.	++	++	+	–	
246.	Coal Tit	*P. ater* L.	+	+	++	–	
247.	Crested Tit	*P. cristatus* L.	++	++	++	–	
248.	Great Tit	*P. major* L.	++	++	++	–	
249.	Blue Tit	*P. caeruleus* L.	+	+	++	–	
250.	Azure Tit	*P. cyanus* Pall.	–	–	–	+	
251.	Nuthatch	*Sitta europaea* L.	+	(+)	–	+	Reported by A. V. Korosov
252.	Treecreeper	*Certhia familiaris* L.	++	++	++	–	
253.	Yellowhammer	*Emberiza citrinella* L	++	+	+++	–	
254.	Ortolan Bunting	*E. hortulana* L.	+	–	+	–	
255.	Little Bunting	*E. pusilla* Pall.	+	–	+	–	
256.	Rustic Bunting	*E. rustica* Pall.	+	–	++	–	
257.	Yellow-breasted Bunting	*E. aureola* Pall.	+	–	+	–	
258.	Reed Bunting	*E. schoeniclus* (L.)	+++	–	+++	–	
259.	**Lapland Bunting**	***Calcarius lapponicus*** **(L.)**	–	–	++	–	
260.	Snow Bunting	*Plectrophenax nivalis* (L.)	–	–	++	–	
261.	Chaffinch	*Fringilla coelebs* L.	+++	+	+++	–	
262.	Brambling	*F. montifringilla* L.	++	+	++	–	
263.	Serin	*Serinus serinus* (L.)	–	–	–	+	

Nn	I	II	III				IV
			N	W	T	A	Source of information
264.	Greenfinch	*Carduelis chloris* (L.)	+	+	+	–	
265.	Siskin	*C. spinus* (L.)	+++	+	+++	–	
266.	Goldfinch	*C. carduelis* (L.)	+	+	+	–	
267.	Redpoll	*C. flammea* (L.)	++	+++	+++	–	
268.	Arctic Redpoll	*C. hornemanni* (Holb.)	+	+	+	–	Kokhanov, 1999
269.	Twite	*C. flavirostris* (L.)	–	–	–	+	Lehtonen, 1943; Zimin et al., 1993
270.	Linnet	C. *cannabina* (L.)	+	–	+	–	
271.	Common Rosefinch	*Carpodacus erythrinus* (Pall.)	++	–	++	–	
272.	Pine Grosbeak	*Pinicola enucleator* (L.)	+	+	+	–	
273.	Parrot Crossbill	*Loxia pytyopsittacus* Borkh.	++	++	++	–	
274.	Crossbill	*L. curvirostra* L.	+++	+++	+++	–	
275.	Two-barred Crossbill	*L. leucoptera* Gm.	+	+	+	–	
276.	Bullfinch	*Pyrrhula pyrrhula* (L.)	+++	++	+++	–	
277.	Hawfinch	*Coccothraustes coccothraustes* (L.)	+	+	+	–	
278.	House Sparrow	*Passer domesticus* (L.)	+++	+++	+	–	
279.	Tree Sparrow	*P. montanus* (L.)	++	++	++	–	
280.	Rose-coloured Starling	*Sturnus roseus* (L.)	–	–	–	+	Koskimies, 1979
281.	Starling	*St. vulgaris* L.	++	+	+++	–	
282.	Golden Oriole	*Oriolus oriolus* (L.)	+	–	+	–	
283.	Jay	*Garrulus glandarius* (L.)	+++	++	+++	–	
284.	Siberian Jay	*Perisoreus infaustus* (L.)	++	++	+	–	
285.	Magpie	*Pica pica* (L.)	+++	++	+	–	
286.	Nutcracker	*Nucifraga caryocatactes* (L.)	+	–	–	+	Zimin et al., 1993
287.	Jackdaw	*Corvus monedula* L.	+++	+++	+++	–	
288.	Rook	*C. frugilegus* L.	++	+	++	–	
289.	Carrion Crow	*C. corone corone* L.	–	–	–	+	Koskimies, 1979; Zimin et al., 1993
290.	Hooded Crow	*C. . corone cornix* (L.)	+++	+++	+++	–	
291.	Raven	*C. corax* L	++	++	++	–	

I–II. List of bird species of the Republic Karelia. The order of species is based on the Catalogue of Birds in the USSR (Ivanov, 1976). The species listed in the Red Data Book of Karelia (1995) are presented in bold type. III. Occurrence pattern and prolificacy: N = nests; W = winters; T= transitory; A = species observed occasionally; / / = used to nest in the past. (+) = presumably nests, winters and stops while migrating according to sightings of birds and evidence for neighbouring territories; +++ = common species which inhabits all biotopes suitable for nesting; ++ = common species which occurs regularly but only in suitable habitats; + = rare species, few sightings. IV. Source of information on species for which no original data is available.

Karelia has sixteen hunting reserves. Of special importance are five reserves, namely the Keretsky, Vongomsky, Shuiostrovsky, Northern Priladozhye and Òuloksky Reserves located in the White Sea and Lake Ladoga island and skerry systems. Other reserves of primary importance include breeding sites of the capercaillie, hazel grouse and black grouse. A large contribution to the conservation of bird fauna is made by the Shaidomsky, Muromsky, Arctic Circle, Kuzova, Andrusovo, Tolvajärvi, Soroksky and West Archipelago Landscape Reserves. Other important territories include the unique Valaam Native Landscape Area, the Nyukhcha Mire Reserve, and the Vazhinsky and Lebyazhye Mires.

Although Karelia has many large protected territories its birds are not protected as well as they should be. The existing network came into being in a more or less haphazard fashion over a number of decades. To begin with little was known about regional bird distribution and so many valuable localities were neglected. Most reserves were established in order to conserve either mires or water bodies alone. Their protection systems usually fail to fully maintain faunistic diversity. Unfortunately, special services are set up and funded only in certain (usually federal) SPAs while other territories are protected only in the conventional manner. The only territories which are genuinely protected today in Karelia are the Kivach and Kostomuksha Strict Reserves and the Paanajärvi and Vodlozero National Parks. However, even there current protection activities are not fully effective due to the small numbers of staff, poor technical facilities and complex environments. Numerous violations of protection regulations in these territories, including large-scale deforestation, the collecting of eggs of waterfowl, the death of broods in fishing nets, the destruction of nesting grounds, the occurrence of devastating fires on islands colonised by birds, the shooting rare species, etc., often cause considerable damage to bird populations.

The present network of protected areas in Karelia is insufficient to protect birds and their habitats as evidenced by the fact that most IBAs of global significance lie outside the existing SPAs. They either overlap SPAs only in part or are located in other poorly protected reserves. In order to conserve Karelia's bird fauna it is necessary to establish a complete regional IBA network, to optimise the pattern of the already existing SPAs, to found new reserves, to correct the boundaries and systems of regulation of some active reserves and valuable native sites and to initiate monitoring operations, etc. Therefore, inventory studies should be continued primarily in potential IBAs as well as in both existing and proposed SPAs.

3.6.2. Zonal and landscape aspects relating to local bird faunas

Introduction. An extensive pool of data concerning the bird fauna and geographical zoology of Karelia and adjacent areas has been accumulated (Bianki et al., 1993; Zimin et al., 1993; Volkov et al., 1995; Hyytiä et al., 1983). The geoornithological and general landscape zoning of East Fennoscandia was performed (Bianki et al., 1993; Sazonov, 1997; Merikallio, 1958; Järvinen, Väisänen, 1980). The schematic map of landscape-ornithological districts of Karelia was compiled (Sazonov, 2001). Below you will find a brief description of the bird fauna and population of the districts identified. An important tool used for zoogeographical comparisons is the method of local faunas, substantiated and tested by the author over the last 5 years of research (Sazonov, 2000).

Methological approach. The principles and criteria used to identify, study and analyse local fauna are as follows. The fundamental principle is a landscape-based approach to the identification of local fauna. Each landscape province (or subprovince) displays its own local faunistic pattern which consists of a dominant landscape type and various zonal and ecological terrain characteristics. In this context the term 'local fauna complex' is understood as meaning a typical combination or pattern of species identified when a key site in any given landscape province is studied. One of the main criteria used to define local fauna complexes is the absence of boundaries of distribution areas of new species on extending the area under study. Thus, according to empirical field data individual local fauna complexes cover areas of between 10–15 and 50–70 thousand ha in the mid-taiga and between 40–50 thousand and 100–150 thousand ha in the north taiga. In protected territories the areas defining local fauna complexes are usually limited by the extent of nature reserves, national parks and wildlife areas. If large agrarian lands or other habitats suitable for settlement and comparable in area to natural forest landscapes (over 3 000 ha) occur within the study territory then corresponding anthropogenic (urban and agrarian) local fauna complexes must be identified and analysed separately.

In order to thoroughly assess the composition of local nesting bird fauna studies should be carried out over periods of at least three years. However, in some cases, especially when initial data is available in existing literature, a one to two year study is sufficient. The composition of local fauna complexes is analysed in detail below only for those areas where bird fauna have been studied in some detail. Other key sites are not used in drawing comparisons. The final list of local fauna complexes includes a synchronous cross-section of bird fauna according to the results of assessments made over the past 20–25 years. Species which nested in the past but are no longer present are disregarded. Species for which reliable proof of nesting has not been established are also excluded. Occasionally nesting species, i.e. birds that nest only once every 10–15 years are also not listed. Cases of nesting far away from the main distribution area are quite uncommon and are of limited zoogeographic value (Zimin, 1977). According to the principles and criteria of the local fauna method the main goals of the study can be attained. These are to standardise faunistic sampling techniques, to compare efforts made to examine key sites and to draw reliable ornithogeographic comparisons.

Tens of lists of species were analysed and processed. Bird species were divided up into a number groups according to their status within local fauna. These were 1) permanent nesting residents (N); 2) species that used to nest in the past (n); 3) occasionally nesting species (E); 4) species nesting in adjacent areas outside the key site, e.g. in agricultural landscapes or in felling areas close to the boundaries of protected territories (V); 5) transient migrants and alien species (M). The first group of species forms the core of local fauna and is used for subsequent zonal-landscape comparisons. Groups 2–4 consist of species which potentially form nesting populations and make up the 'periphery' of a given local fauna. To cast light on the patterns of their stay, long-term large-scale evaluative studies are required.

In order to analyse the zoogeographic composition of local fauna a revised classification of faunistic groups in the taiga zone based on the concepts of B.K. Shtegman (1938) and B.B. Brunov (1980) and largely published earlier (Sazonov, 1997) was used. To obtain data on the total density of bird populations in prevailing types of landscape, large-scale field estimates of bird fauna were conducted using conventional techniques and bird detection transects (Volkov et al., 1995; Sazonov, 1997).

Results. Based on extensive data obtained during faunistic, geozoological and ornithogeographic studies carried out in Karelia over the past twenty years a detailed scheme showing the landscape-ornithological demarcation of Karelia has been produced. Thus, Karelia was subdivided into sixteen landscape-ornithological provinces: 1) South Lapland province, 2) Circumpolar lake province, 3) Circumpolar White Sea province, 4) Northern White Sea province, 5) Southern White Sea province, 6) Kuitozero, 7) Northern aapa, 8) Reboly, 9) Segozero selka, 10) Vygozero, 11) Inland Karelia, 12) Zaonezhye, 13) Northern Lake Vodlozero area and the upper Vyg river, 14) Northwestern Lake Ladoga region, 15) Ladoga-Onega Isthmus and 16) Vodla (Fig. 52). The above provinces are briefly described below in terms of the composition of local fauna. NB. Throughout the following descriptions of provinces the classification of species in terms of northern, southern, southeastern, eastern, etc. refers to their distribution areas with respect to each particular province in question.

1. South Lapland province. Ornithogeographically this is province is rather atypical of Karelia. It forms part of the Lapland ornithogeographic region (Bianki, 1922) while the remainder of Karelia's north-taiga subzone lies within the Pomor region. Common species are *Cinclus cinclus, Turdus torquatus* and *Pinicola enucleator*. These are not found elsewhere in Karelia. Some species, e.g. *Melanitta fusca, Mergus albellus, Buteo lagopus* and *Luscinia svecica* which normally nest here are occasionally observed in small numbers in other areas. The bird fauna and populations of the province has been described earlier (Sazonov, 1997). Altogether, 162 bird species have been reported from the province, 142 of which nest here.

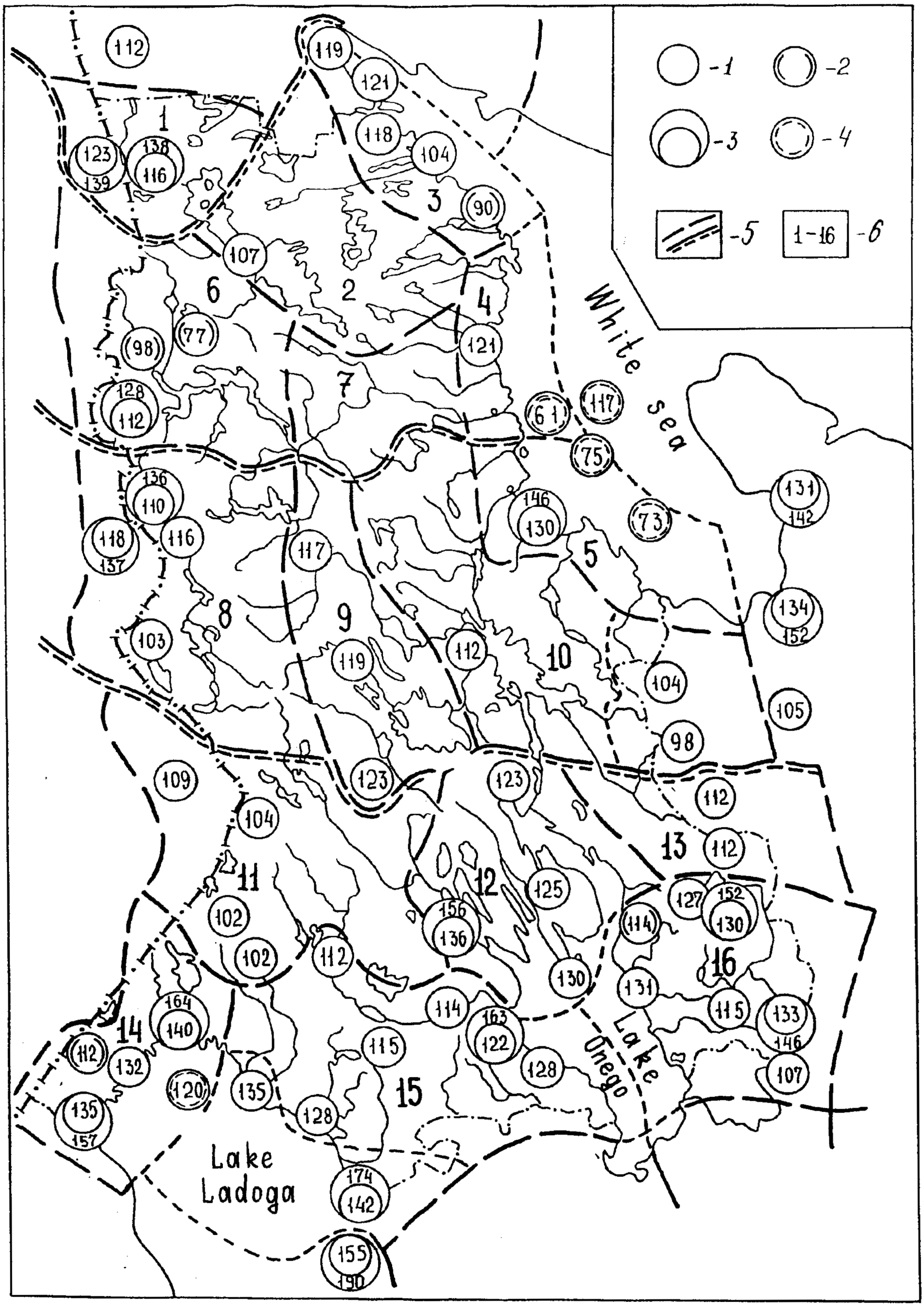

Fig. 52. Species diversity of local fauna in Karelia and adjacent territories

1. local fauna studied in detail; 2. superficially studied local fauna; 3. associations of natural local fauna, local fauna of natural and anthropogenic origin; 4. & 5. boundaries and numbers of landscape-ornithological provinces. Numbers in circles indicate populations of nesting species. The boundaries of zoogeographic regions are shown according to the scheme published (Sazonov, 1997)

The Lake Paanajärvi area marks the southern boundary of Lapland forest fauna and extends across the White Sea-Baltic Sea watershed. North-taiga, mid-taiga, hypoarctic and arctic species make up 47% of local species diversity (hypoarctic and arctic species accounting for 21%). This represents the highest proportion of northern species of bird fauna for any part of inland Karelia. The percentage of northern bird species varies from 52% in Alakurtti to 59% in Central Lapland (Lapland Nature Reserve), arctic and hypoarctic species making up 27% in each case. European broad-leaved forest birds account for 15.5% of all species in Paanajärvi National Park and 17% in Oulanka Park, Finland. In the areas of low-mountain spruce taiga which dominate Oulanka Park the total bird population density is less than 90 pairs/km^2. This is low figure for a northern zoogeographic province.

2. Circumpolar lake province. Local bird fauna complexes here are poor in terms of species diversity. At the Sofporog site in the Lake Topozero-Lake Pyaozero area only 107 nesting species were reported, of which northern species make up 43% and birds of southern origin 20%. The proportion of hypoarctic and arctic species is 16%, somewhat lower than for Paanajärvi. Pine landscapes with a low bird population density of 124 pairs/km^2 prevail. Populations are dominated by north taiga, mid-taiga, hypoarctic and arctic species. *Parus cinctus* is of common occurrence. During the 1989 vole populations were high and consequently *Strix nebulosa, S. uralensis, Aegolius funereus, Circus cyaneus, Buteo lagopus* and *Lanius excubitor* were observed at breeding sites. *Numenius phaeopus* is common on mires. A few pairs of *Emberiza pusilla* have been seen in the areas of Sofporog and Kestenga. The water bodies located in the province are markedly oligotrophic. One interesting observation was the breeding of *Sterna paradisaea*. This species is uncommon on other mainland lakes south of Lake Topozero. *Melanitta fusca, M. nigra* and *Aythya marila* also nest here. *Limosa lapponica* was seen during the breeding season. Of particular interest is the nesting of the southern species *Emberiza hortulana* and *Parus caeruleus*. *Milvus migrans* was encountered during the summer. Generally speaking, this province has not been adequately studied. In all 137 bird species were reported of which 124 are known to nest. Special faunistic studies are required in the central part of the province, especially on large lakes such as Topozero, Engozero, Keretozero and Tiksheozero.

The Circumpolar, Northern White Sea and Southern White Sea landscape-ornithological provinces form the White Sea subregion. Local fauna complexes are more diverse in the White Sea region than on the mainland. Such a pattern is primarily due to the wealth of waterfowl and semiaquatic birds which constitute about 30% of all nesting species in coastal terrains and up to 36–37% in archipelago systems. The archipelagoes located in the open sea are greatly affected by the arctic climate. They host highly specific terrestrial biocenoses (including extrazonal tundra) and highly characteristic local bird fauna. Thus, archipelago landscapes may be attributed subprovince status.

3. Circumpolar White Sea province. Potentially highly productive rocky ridge (selka) landscapes are common along the Kandalaksha Bay coastline where pine forests dominate. The shoreline with its narrow fjord-like bays is highly fragmented. Waterfowl and semiaquatic birds (mainly sea birds) that breed on the mainland account for up to 31% of local fauna while those nesting on the islands in the Kandalaksha Reserve contribute up 37%. Northern bird species prevail (48–51%). Arctic and hypoarctic species make up 25–27% and are slightly less prolific. The proportion of southern birds is relatively low (14–16%) although in the Kandalaksha area they account for 19% of all species. Of very greatest interest are the stable nesting populations of *Emberiza pusilla* and *Pinicola enucleator* in Kandalaksha Bay. Indeed, this is the only breeding site for *Pinicola enucleator* in Karelia. The population density of *Parus cinctus* is typically high (3–4 pairs/km^2). The population of *Gavia stellata* remained stable even during the period of collapse of species populations in Karelia. *Phalacrocorax carbo* started to spread during the mid-1960s. The largest colony of this species in Karelia has been reported on some outer islands in the Keret Archipelago. This location is listed as a wetland of international significance according to the Ramsar Convention.

An overall population density of 225 pairs/km^2 was reported in the selka pine landscapes of Grinido. This is the highest density reported so far from any location in the northern zoogeographic province. The bird population is dominated by north taiga, mid-taiga, hypoarctic and arctic species. Boreal-nemoral forest birds are also fairly common (21%). Their proportion in low-mountain spruce stands close to near Lake Paanajärvi is about the same (23%) presumably because palaearctic animals and birds typical of European broad-leaved forests migrate from the north along the Scandinavian corridor to Lapland and northern Karelia. Southern species rare to polar regions are commonly reported from the Kandalaksha area. Thus, *Tringa ochropus, Scolopax rusticola, Garrulus glandarius, Sylvia curruca, Phylloscopus sibilatrix, Prunella modularis, Emberiza hortulana, Carduelis cannabina,* and *Carduelis chloris*, etc., were all reported to breed (Kokhanov, 1987).

The bird fauna of the province has been thoroughly studied. Altogether, 232 bird species were reported, 153 of which nest in the province.

4. Northern White Sea province. Some southern species such as *Jynx torquilla, Sylvia communis, Phylloscopus sibilatrix, Acrocephalus dumetorum, Parus caeruleus* and Carduelis *chloris* occur in the South Belomorian province but are not observed to breed in the Northern White Sea province. Many southern species, for example, *Scolopax rusticola, Columba palumbus, Garrulus glandarius, Sylvia curruca, S. borin, Acrocephalus schoenobaenus,* and *Troglodytes troglodytes*, are present but only in small numbers. Local fauna complexes are highly diverse on heavily paludified plains (e.g. 121 species at Pongoma). Northern birds make up 46% of all species while southern species account for 16%. Near Kem the proportion of southern species rises to 21%. Low population densities (115 pairs/km^2) are characteristic of highly paludified pine landscapes. *Parus cinctus* and *Emberiza pusilla* are common. Some rare Arctic species such as *Tringa erythropus* and *Calidris temminckii* were observed to breed. *Phaloropus lobatus* and *Limosa lapponica* used to breed here in the past. The largest primeval forest area of the White Sea region has survived

on the sea coast north of the Vonga Bay. The shoreline and aquatoria of the locality form wetlands of national significance with many waterfowl and sea birds gathering there to breed and moult. Migrating *Cygnus bewickii, Branta bernicla* and sea ducks also stop over in large numbers. The nesting group formed by *Haliaeetus albicilla* and *Pandion haliaetus* is the largest in the Karelian sector of the White Sea. *Falco peregrinus* and *Aquila chrysaetos* are amongst the breeding birds. A protected area is needed in the Pongoma area.

The fauna of the Kuzov Archipelago is quite unique. Northern birds make up 52% (the highest proportion reported anywhere in Karelia) while arctic and hypoarctic species account for 33%. Southern birds constitute only 11.5%. Hydrophilic birds make up 36% of all species (the highest value) and form over two thirds of the total bird population. A colony of *Alca torda* (350 pairs), the largest in the White Sea region, is located on Verkhny Island. Beloguzikha Island hosts one of the largest colonies of *Larus fuscus* (45 pairs) in the northern part of Onega Bay. Some rare species, e.g. *Stercorarius longicaudatus* and *Anthus spinoletta*, are observed to nest in the province.

In all 176 bird species are known in the province with 141 species nesting here. Further studies are needed in order to assess the bird fauna of the proposed Pongoma Park which, together with the Kalevala Park, will form a part of Karelia's network of protected areas.

5. Southern White Sea province. This is located in a transitional zoogeographic region. Southern traits of its fauna are more distinct here than in other parts of the White Sea region. In the mainland part of the Soroksky Wildlife Reserve southern birds make up 21.5% of all species while northern birds contribute 41%. On the archipelago systems southern birds account for 16% (Kondostrov), 13% (Zhuzhmui) and 11.5% (Kuzov). Southern species which are scarce to the transitional region, including *Circus aeruginosus, Pernis apivorus, Asio otus, Parus caeruleus, Saxicola torquata, Phylloscopus sibilatrix, Ph. trochiloides, Sylvia communis, Emberiza aureola* and *Carduelis chloris*, were found to breed here. *Acrocephalus schoenobaenus* is common on the seashore and *Porzana porzana* has been encountered during the breeding season.

Examples of rare species nesting in the archipelagoes are *Phalacrocorax carbo* (Zhuzhmui, Parusnitsy), *Tadorna tadorna* (Zhuzhmui) and *Fratercula arctica* (Sennukhi sand bars, the only breeding ground of this species in the White Sea). Sennaya Luda Island is home to one of the largest colonies of *Larus fuscus* (80–100 pairs) in Onega Bay. *Phylloscopus borealis* and *Emberiza pusilla* are common on the mainland and on some archipelago islands. *Parus cinctus* was only encountered on B. Zhuzhmui Island. The population of *Gavia stellata* is stable in coastal terrains while the nesting density of *Somateria mollissima* remains high on remote archipelagoes. The area is important for the migration of waterfowl in North Russia. Furthermore, most of the White Sea population of *Somateria mollissima* remains here throughout the winter season. Hundreds of gulls of the species *Larus argentatus, L. hyperboreus* and *L. marinus* winter in extensive herring and *Eleginus* winter fishing areas. In all, 202 bird species have been reported from the province, 152 of which nest here. Further assessment studies are required as the province hosts concentrations of waterfowl and semiaquatic birds unique to North Europe.

6. Kuitozero province. This is part of the Northern zoogeographic region. Northern birds make up 41% and southern species 19% of local fauna of the proposed Kalevala National Park. Of interest is the nesting of the northern species *Phylloscopus borealis, Emberiza pusilla, Parus cinctus, Buteo lagopus* and *Mergus albellus*. The rare eastern species *Emberiza aureola* and *Larus minutus* were also observed to breed. The park provides shelter for a large number of protected and vulnerable species, including groups of *Haliaeetus albicilla* and *Pandon haliaetus* (5 and 12 pairs respectively), the largest known in the border forest zone. *Aquila chrysaetos* and *Falco peregrinus* also nest here. Some 10 pairs of *Milvus migrans* occupies an isolated settlement in the area including the shores of Lake Verkhneye Kuito. This is also an important breeding area for *Gavia arctica, Cygnus cygnus* and *Anser fabalis.* Of significance were the stable populations of *Cygnus columbianus* on local lakes (up to 50–60 birds in May-June). Some groups remain there as late as 10th – 12th July. An overall population density of 135–160 pairs/km^2 (moderate for the northern region) was reported in prevailing landscape types. Nesting population densities of most southern birds were much lower here. Thus, for example, the common *Fringilla coelebs* is absent from breeding sites in some watershed terrains located between lakes Kuito and Paanajärvi (Tungozero and the southern bank of the River Tavajoki). Altogether, 172 bird species are known in the province, 132 of which nest here.

7. Northern aapa province. This province contains extensive Karelian ring-type aapa mires. Indeed, Yupayuzhsuo Mire covers an area of about 40 000 ha and is the largest mire in Karelia. Summer aerial surveys of a chain of aapa mires between Lake Topozero and the River Kem have revealed the nesting density of *Cygnus cygnus* to be one of the highest in the Kola-Karelian region. The swan population here is estimated at 1050. A proposal has been made to incorporate this territory into a protected wetland of international or at least national significance (Bianki & Shutova, 1987; Boch & Kuznetsov, 2000). Preliminary studies and surveys have shown that these breeding sites of swans are still important. The largest populations of *Cygnus cygnus* as well as the most extensive breeding sites of *Anser fabalis* in the Kalevala district are concentrated on Yupyauzhsuo Mire. *Gavia arctica* and *Grus grus* are both common while *Haliaeetus albicilla* and *Pandion haliaetus* were observed to nest. *Aquila chrysaetos, Falco columbarius* and other endangered species were also reported. *Cygnus columbianus* remained on local lakes into June. Many other rare species, including the Arctic wood-cock *Lumicolae,* are assumed to nest here.

Insufficient is known about the bird fauna of the province. Available evidence shows that it is inhabited by a total of 125 bird species with 110 species nesting here. Some time ago a proposal was made to establish a Yupyauzhsuo Mire Reserve covering an area of 60 000 ha (Volkov et al., 1995). However, one option is to establish a landscape reserve with protected area status. In any case, this mire is already included in the prospective list of the Ramsar

Convention and will be granted wildlife reserve status (Boch & Kuznetsov, 2000). Comprehensive studies need to be carried out in order to assess the ecosystems, flora and fauna of the proposed Yupyauzhsuo protected area.

8. Reboly province. Along with the Segozero selka and Vygozero provinces Reboly is part of the transitional zoogeographic region in which population densities of northern and southern species are roughly equal. The bird fauna and populations of the Kostomuksha Reserve and the environs of Kostomuksha have been described earlier (Sazonov, 1997; Zimin & Sazonov, 1997). Northern birds make up 39% of bird fauna while southern species contribute 21%. In the vicinity of Kostomuksha the proportion of southern birds increases to 25% while that of northern species falls to 35%. In the area of the proposed Tuulos National Park northern birds account for 37% of local fauna and southern species 22%. Most landscape types in this province host moderate overall bird population densities (the average figure for the Kostomuksha Reserve being 179 pairs/km^2). Some rare northern species such as *Gavia stellata, Mergus albellus, Buteo lagopus, Parus cinctus, Phylloscopus borealis, Tarsiger cyanurus* and *Emberiza pusilla* were reported to nest near Kostomuksha. Examples of nesting southeastern birds include *Ficedula parva, Phylloscopus trochiloides, Emberiza aureola, Larus minutus* and *Milvus migrans*. Some southern European species, e.g. *Sylvia atricapilla, Hippolais icterina, Emberiza hortulana* and *Carduelis chloris*, breed occasionally. *Turdus merula* was only observed to nest in Tuulos Park.

A total of 190 bird species is known in the region, 140 of which nest here.

9. Segozero selka province. Slightly paludified pine-dominated ridge (selka) landscapes are common here. They form a chain of large and well-defined northwest oriented crystalline ridges extending from the Lake Yangozero-Lake Sovdozero area across Selgi, Maslozero and Yelmozero as far as the River Chirka-Kem and Lake Nyuk. Large depressions between the ridges are occupied by other landscape types such as highly paludified terrains containing aapa mires alternating with high selkas. In terms of its characteristic biotic diversity parameters this province may be described as a boreal-nemoral island situated within an otherwise typical north-taiga zone. Large areas of this selka landscape had at some stage in the past been cleared for agricultural purposes. Practically all selka terrains with fertile soils and productive stands were used for swidden agriculture. Today these areas are covered by pine-deciduous and deciduous forests with small patches of mosaic agricultural landscapes.

Highly diverse local fauna and a high bird population densities are characteristic. Southern birds constitute 21% of all species in the northern part of the province and 24–29% in the southern part. Some European broad-leaved forest birds and southern palearctic species such as *Pernis apivorus, Scolopax rusticola, Columba palumbus, Turdus merula, Aegithalos caudatus, Parus major, Phylloscopus sibilatrix, Sylvia borin, S. communis,* and *Lanius collurio* are common close to Lakes Yangozero, Sovdozero and Maslozero. Examples of southeastern species are *Ficedula parva, Phylloscopus trochiloides, Acrocephalus dumetorum, Emberiza aureola* (only near Lake Sovdozero) and *Dendrocopos minor.* The rare southern species *Porzana porzana, Strix aluco, Caprimulgus europaeus, Luscinia luscinia, Sylvia atricapilla* and *Emberiza hortulana* (which nested here in the past) were only observed in the Lake Sovdozero area. The most interesting north-taiga species is *Parus cinctus.* As a result of large-scale deforestation in East Fennoscandia over the past fifty years its distribution area has moved northwards. *Parus cinctus* was only encountered in the proximity of Tiksha where it is quite common whereas in the late 19th and early 20th centuries it was common throughout the area between lakes Segozero and Vygozero. In the southern part of the province *Parus cinctus* occurs as far as Povenets.

Considering that these selka landscapes occur within the transitional region the overall bird population densities found there are relatively high, i.e. 307 pairs/km^2 in the south (Sovdozero) and 220–250 pairs/km^2 in the north (Tiksha). In all, a total of 169 species was reported for this province, 140 of which 140 nesting ones here. As the province has been inadequately studied further studies should be conducted with special attention paid to the areas of Lake Segozero and Lake Ondozero.

10. Vygozero province. The largest landscape-ornithological province in Karelia, Vygeozero includes the River Ileksa basin-Windy Belt ridge subprovince to the east. There, the species diversity of local faunas is lower, the faunistic complexes consist of a high proportion of northern species, as well as eastern and southeastern species. The only local fauna studied so far is in the vicinity of Segezha in the central part of the province, where northern species make up 36% and southern birds 24% of species diversity. In the Ileksa River basin the proportion of northern birds rises to 39–42% while southern species account for 20–22%. Some European broad-leaved forest species are absent whereas southeastern birds such as *Acrocephalus dumetorum, Ficedula parva, Phylloscopus trochiloides* and *Emberiza aureola* are observed to nest. In 1997 the southeastern species *Hippolais caligata* was seen nesting on a felling site near Lake Pelozero at the boundary of Vodlozersky Park. This is the northernmost sighting of this species anywhere in the western part of the taiga zone. Of special interest is the presence of nesting *Parus cinctus* (southwards as far as Lake Tun) and *Emberiza pusilla* (Lake Kerazhozero) in the Ileska river basin. These are both northeastern species.

Together with the Northern lake and the Northern aapa provinces, the Lake Vygozero area remains one of the least studied in Karelia. It provides shelter for a total of 187 bird species of which 144 nest. A thorough survey of the bird fauna is urgently needed. Of special interest is the Sumozero glacial-accumulative structure located between lakes Vygozero and Sumozero where the proposed Prishvin National Park covering an area of 40 000–50 000 ha is likely to be established. Dome-shaped hills with numerous small lakes in between characterise the landscape. The province contains over 700 water bodies in various proposed protected areas and can with little exaggeration be called ‘The Land of a Thousand Lakes’. Its landscapes are scenic and recreationally attractive. The history of the Vygozero province is closely connected with the writer M. I. Prishvin who visited Korosozero, Pulozero and other villages on many occasions during the early part of the 20th century. The territory has been subject to widespread deforestation leaving a number of old pine forest fragments amidst a mass of fifty to sixty year old stands. *Rangifer tarandus fennicus* and *Gulo gulo* are found here and the population density of *Tetrao urogallus* is very high. *Gavia stellata, Cygnus cygnus, Anser fabalis, Grus grus, Haliaeetus albicilla, Pandion haliaetus* and other vulnerable species were seen nesting. The ecosystems, flora and fauna of the proposed Prishvin Park need to be studied thoroughly.

11. Inland Karelia. Together with the remaining provinces listed here, Inland Karelia belongs to the southern zoogeographic region. It covers most of the Suojärvi administrative district which for game management purposes is classified as part of Mid-Karelia. Biogeographically the province forms a taiga peninsula extending into much of southern Karelia. It is surrounded by terrain types with more favourable soil and climatic conditions and, consequently, more diverse bird flora containing a greater proportion of southern species (Segozero selka, Zaonezhye, the Ladoga-Onega Isthmus and the northwestern Lake Ladoga region). A cold mesoclimate, poor soils and a high degree of paludification are responsible are synonymous with the prevalence of relatively unproductive landscapes. The original pine taiga has been clear felled on a massive scale but deciduous species have not thrived on these sites.

The species diversity of local fauna complexes is low but aboriginal north-taiga, hypoarctic and arctic species are relatively well represented. Northern birds are more abundant here than in the surrounding territories and account for 32% in the southern end and 35% in the central and northern parts of the province. Southern species are less common in all local fauna complexes and contribute only 26–27% in terms of species diversity. At the same time, these southern birds display the highest population densities (47–55% of total bird population). *Perisoreus infaustus* and *Bombycilla garrulus* are common in Inland Karelia but are not found in territories to the south. High population densities are reported for *Tetrao urogallus, Anas penelope, Grus grus, Tringa nebularia, Picoides tridactylus* and *Emberiza rustica.* High nesting densities are associated with various hypoarctic and arctic species including *Gavia arctica, Lagopus lagopus, Pluvalis apricaria, Tringa glareola, Numenius phaeopus* and *Anthus pratensis.* The extensive breeding grounds of *Cygnus cygnus* and *Anser fabalis* found in the province are the southernmost in East Fennoscandia, the Lake Tolvajärvi sites having been used regularly over the past 120 years. Some rare northern species such as *Phylloscopus borealis, Philomachus pugnax, Lymnocryptes minimus* and *Sterna paradisaea* (reported occasionally) were also seen nesting.

At the same time many southern species are either scarce or not found. *Circus aeruginosus, Aquila clanga, Caprimulgus europaeus, Lullula arborea, Parus coeruleus, Sylvia atricapilla, Acrocephalus schoenobaenus, A. palustris,* and *Emberiza hortulana* nest very seldom but were found in the province along with *Ficedula parva, Acrocephalus dumetorum, Phylloscopus trochiloides* and *Emberiza aureola.* Other rare southern species were reported from the periphery of the Suojärvi district in terrain types lying in the adjacent landscape provinces of Yangozero-Sovdozero, Suojärvi-Toivola-Hautavaara and Suistamo-Leppasyrja-Soanlahti. These species include *Podiceps cristatus, Botaurus stellaris, Porzana porzana, Strix aluco, Asio otus, Streptopelia turtur, Dendrocopus minor, Oriolus oriolus, Luscinia luscinia,* and *Coccothraustes coccothraustes*, etc. Overall population densities are as low as 234 pairs/km^2 in moderately paludified pine landscapes (Piitsjoki), 132 pairs/km^2 in rupicolous pine stands on esker ridges (Tolvajärvi) and 112 pairs/km^2 in the highly paludified pine landscape of Patvinsuo. Some waterfowl such as geese, barnacles, swans and sea ducks migrate over Inland Karelia. *Branta leucopsis* and *Branta bernicla* are known to follow three narrow migration routes, namely, Tolvojärvi, Piitsjoki-Suojärvi and Kasnaselka. A total of 189 bird species is known in this province, 141 of which nest here. It is considered desirable to continue assessment studies in the area of the Nelgomozero glacial-accumulative structure in the eastern part of the province.

12. Zaonezhye province. Unlike other landscape provinces in southern Karelia, Zaonezhye consists of variety of large ridge (selka) landforms and fertile brown forest and sod-shungite soils. It is slightly paludified areas and has a relatively mild mesoclimate. Zaonezhye used to be one of the northernmost areas of agriculture. Biogeographically it forms a nemoral peninsula in which the distribution areas of many southern bird species extend northward as far as northern Obonezhye. The bird fauna of the Zaonezhye Peninsula has been described earlier in detail (Hokhlova, 1977,1998; Sazonov, 1999; Hokhlova et al., 2000). The compositions of local fauna complexes in the Kivach Reserve, the proposed Zaonezhye National Park and the Kizhi Federal Zoological Wildlife Reserve have all been surveyed. These ecosystems have been transformed by human activities to varying degrees. Minimum transformation has taken place in Kivach, more in the Zaonezhye Park and a large degree in the Kizhi Reserve. The greater the human influence the higher the proportion of southern species. Thus, the figures for these three areas are Kivach 29%, Zaonezhye Park 34% and Kizhi Reserve 35%. At the same time the species diversity of northern birds is 30% in Kivach, 27% in Zaonezhye Park and 24% in the Kizhi Reserve. In the area of Povenets (northern Zaonezhye province) southern birds account for 28% of all species while northern species contribute 31%. The overall bird population density in the selka (tectonic ridge) type landscapes is one of the highest in Karelia, i.e. 426 pairs/km^2 in selka pine stands of mixed age structure and 331 pairs/km^2 in spruce stands growing on morainic plain with crystalline ridges. The province has been studied thoroughly. So far 232 bird species have been reported with 164 nesting in the province.

13. Northern Vodlozero and Upper River Vyg province. Ornithogeographically speaking, this province resembles that of Inland Karelia albeit on a smaller scale. Thus, it forms a highly paludified peninsular of taiga forest. Northern species make up 36–37% (the highest proportion for local fauna complexes in southern Karelia) while southern species contribute only 22–24% (correspondingly the lowest figure for southern Karelia). The overall bird population density in the prevailing highly paludified pine-dominated landscape type is 114 pairs/km^2 (the lowest figure recorded for southern Karelia). Important breeding grounds for *Cygnus cygnus* and *Anser fabalis* are located in the

northern part of the Lake Vodlozero area and in the upper reaches of the Vyg river basin. *Haliaeetus albicilla* and *Pandion haliaetus* are common. *Aquila chrysaetos, Falco peregrinus, F. columbarius, Milvus migrans* and other rare predatory birds have been seen nesting. Hypoarctic and arctic species such as *Lagopus lagopus, Pluvalis apricaria, Numenius phaeopus, Philomachus pugnax, Anthus pratensis,* and *Carduelis flammea* etc., are common on mires. *Emberiza pusilla* is encountered occasionally but evidence of its nesting here has not been firmly established. *Tarsiger cyanurus* (2 pairs in 1999) has also been reported.

Altogether 167 bird species are known of which 126 nest in the province. Assessment studies of the upper River Vyg are considered desirable.

14. Northwestern Lake Ladoga province (Priladozhye). Natural ecosystems here are highly productive and boreal-nemoral south-taiga cenoses are of widespread occurrence. Thus, local flora and fauna complexes are highly diverse with a total of 220 bird species known for the province including 169 nesting species. The Valaam and Western Archipelagoes together form a subprovince in its own right.. These are the only permanent nesting grounds in southern Karelia for arctic and North Atlantic species such as *Somateria mollissima, Melanitta fusca, Haemotopus ostralegus, Larus marinus* and *Sterna paradisaea*. Other nesting species include *Sterna caspia* and *Branta canadensis* (Medvedev & Sazonov, 1994).

The northwestern Lake Ladoga province has a unique wealth of hydrophilic birds which mostly inhabit the skerries and archipelagoes. This largely explains the unusually high local faunistic diversity of the Ladoga skerries, i.e. 135–140 nesting species. There are between 35 and 38 hydrophilic species which account for 26–28% of the faunal diversity of the coastal-skerry zone. The Valaam Archipelago provides permanent nesting grounds for 39 hydrophilic bird species (32.5% of species diversity). The province exhibits the highest species diversity and population densities of European broad-leaved forest birds anywhere in Karelia. In the Ladoga skerries southern birds account for 37–39% of species diversity and northern species contribute 13–16% (the lowest value for southern Karelia). Northern species are more common in the Valaam Archipelago (26% of species diversity) which provides nesting sites not only for North Atlantic and Arctic birds, but also for some northern species such as *Picoides tridactylus, Lanius excubitor, Anthus pratensis, Luscinia svecica, Loxia leucoptera* and *Fringilla montifringilla.*

The Ladoga skerries is Karelia's most important breeding area for populations of *Podiceps griseigena, Pod. cristatus, Porzana porzana, Fulica atra, Aythya fuligula, A. ferina, Anas querquedula* and *A. clypeata* and nesting grounds for *Botaurus stellaris, Podiceps auritus, Anas strepera* and *Limosa limosa.* The Ladoga skerries host Karelia's largest colonies of *Larus ridibundus* and have been used as nesting sites by *L. minutus* since 1988. *Gavia arctica* is very scarce with only two or three pairs being reported along the periphery of the skerries. The archipelagoes provide shelter for the largest colonies of *Larus argentatus* in Karelia. *Mergus serrator* also nests in large numbers. *Larus fuscus, Sterna hirundo* and *St. paradisaea* form several large colonies.

Overall bird population density in forest landscapes is as high as 430–530 pairs/ km^2 in the skerries and 315–380 pairs/ km^2 on the mainland. The highest nesting densities in Karelia for various southern forest species, i.e. *Strix aluco, Garrulus glandarius, Parus caeruleus, Turdus merula, Hippolais icterina* and *Sylvia atricapilla* are recorded here. *Oriolus oriolus* is common while *Cocothraustes cocothraustes* is often observed. *Perdix perdix* continues to nest in the northwestern part of Lake Ladoga region but has disappeared from the rest of Karelia. *Bubo bubo* appears to come from neighbouring parts of Finland and has formed a stable group of some 10 pairs. However, *Emberiza rustica, Fringilla montifringilla, Loxia leucoptera* and *Tringa nebularia* occur in small numbers only on the mainland. *Perisoreus infaustus* and *Bombycilla garrulus* are absent as are the mire species *Lagopus lagopus, Pluvialis apricaria, Numenius phaeopus,* and *Tringa glareola,* etc.

15. Ladoga-Onega Isthmus. This lies in the centre of southern Karelia and displays moderate species diversity and population densities for northern and southern species as well as both European and Eurasian birds. The Olonets Lowland together with the Salmi Plain and the Mantsinsaari-Lunkulansaari Islands each rank as a subprovinces in their own right. Agricultural land covers an area of 16 000 ha in the Olonets Plain where an open, steppe-like landscape unusual for the taiga zone is formed.

Southern birds make up 33–37% of local fauna but in the eastern Lake Ladoga region (Priladozhye) this figure increases to 36–39%. The proportion of northern species varies from less than 20% in Priladozhye to 22–27% in western Prionezhye. The proportion of southern birds in faunal complexes inhabiting agrarian landscapes (Olonets and Shuya agricultural lands) is especially high at 38–39%. The isthmus is dominated by landscapes with moderate bird population densities of 270–350 pairs/ km^2. In some anthropologically transformed forests overall population density reaches 504–564 pairs/ km^2. Over the past decade the distribution areas of *Circus aeruginosus* and *Limosa limosa* have expanded so that these species now nest in the Shuya and Olonets agricultural area. Pairs of *Haemotopus ostralegus* were seen nesting in the fields of Shuya and in Voznesenye. In the Shuya farming area near Petrozavodsk the population of *Anthus pratensis* has increased significantly and a nesting group of *Luscinia svecica* has formed with 10–12 pairs reported in 1999–2000. A breeding colony of *Hippolais caligata* consisting of five pairs was recorded in 1999. *Saxicola torquata* and *Motacilla citreola* also nest occasionally. *Xenus cinereus* has been nesting here since 1982 but its numbers vary substantially from year to year.

The Olonets Isthmus hosts a total of 263 bird species, 176 of which are known to nest. Since 1991–1992 *Anser albifrons* and *Anser fabalis* have gathered in large numbers during their spring migration. Hundreds of thousands of migrating geese stop off on the Olonets plain in spring and tens of thousands stay for a longer period of time. Other visitors include flocks of *Branta leucopsis* and small groups of *Anser erythropus* (Zimin, 1998). Smaller flocks of migrating geese and barnacles are reported every spring from the Shuya fields near Petrozavodsk, on the Ladva and Korza Lowlands (Essoila), and on agricultural lands in the northern Zaonezhye Peninsula and near Povenets. Up to 5 000 *Anser albifrons* and *A. fabalis* were seen on a single occasion in the Shuya area with around 25 000–30 000 birds reported for the whole spring. In addition, flocks of *Branta leucopsis* numbering up to 300 as well as individual *Anser erythropus* stop off there.

16. Vodla province. This province covers most of the Pudozh administrative district. Local fauna complexes are dominated by southern birds (31–35%), northern species being less abundant (23–25%). East of Lake Onega eastern and southeastern birds occur more often at breeding sites. Examples of flood-plain biotope species are *Milvus migrans, Oriolus oriolus, Acrocephalus dumetorum, Emberiza aureola, Saxicola torquata, Hippolais caligata* and *Locustella lanceolata*. In the Pudozh district high populations and nesting densities are reported for *Strix uralensis, Glaucidium passerinum, Ficedula parva, Phylloscopus borealis, Ph. trochiloides, Emberiza rustica* and *Loxia leucoptera*. To date *Tarsiger cyanurus* has only been reported in Vodlozero National Park (four pairs in 1999). Over the past few years pairs of *Haemotopus ostralegus* have been seen nesting on the eastern shore of Lake Onega at the mouth of the River Vodla.

At the same time the South European species *Lullula arborea* and *Emberiza hortulana* do not breed in the Pudozh district while *Parus caeruleus* and *Carduelis chloris* are present only in small numbers. *Turdus merula*is a new species to the province. Along with the aforementioned species *Phylloscopus sibilatrix, Sylvia atricapilla, Parus major* and *Garrulus glandarius* are absent from the terrains to the north of Lake Vodlozero. Other western species such as *Prunella modularis, Troglodytes troglodytes, Certhia familiaris, Parus cristatus, Ficedula hypoleuca, Jynx torquilla* and *Pernis apivorus* are present in small numbers. In all, there are 198 bird species known in this province, 161 nesting here. Vodlozer National Park plays an important role in maintaining the species diversity of western Eurasian taiga birds. Indeed, this considered to be the second most important area for nesting bird fauna in East Fennoscandia. In all, 71 rare and endangered species are found here, 59 of which are listed in the Red Data Books of Russia, Karelia, the Arkhangelsk Oblast and East Fennoscandia. The park hosts the largest breeding site of *Cygnus cygnus* and *Anser fabalis* (80–90 and 40–50 pairs, respectively). Furthermore, it provides shelter for the largest group of piscivorous predatory birds in North Russia. These include *Pandion haliaetus* and *Haliaeetus albicilla* (35 and 45 pairs respectively). *Milvus migrans* (17 pairs) and *Aquila chrysaetos* (7–8 pairs) also nest here while *Aquila clanga* and *Falco vespertinus* have both been reported. Other nesting birds include *Falco peregrinus, Gavia stellata, Mergus albellus, Larus fuscus, Bubo bubo, Picus canus, Dendrocopus leucotos, D. minor* and many other rare species. Altogether, 204 bird species inhabit in the park including its Arkhangelsk segment and 153 of these are known to nest there.

Conclusion. The local fauna method employing criteria and principles developed earlier is proposed as a basis for faunistic monitoring. Local fauna complexes most representative of each landscape province will be selected. Key sites outside urban and extensive agricultural areas will be preferred. In the final stage of the study a record book containing basic data such as names, geographic coordinates, a list of bird species and their status, the length of the study period, the researchers involved, references, etc. will be presented. Data in the book will be updated continuously and revised at five to ten yearly intervals according to the amount of new faunistic information available.

3.7. Insects (Some results of entomofaunistic studies in Karelia during 1950–2001)

Introduction. The entomofauna of Russian Karelia is relatively well known compared with that of other regions of North Russia belonging to the taiga zone. At the time of writing some 8 000 species of insects are known from the present Karelian territory and more species are likely to be found. It should be noted that in neighbouring Finland with its similar nature nearly 20000 insect species are known (Silfverberg, 2001; Uhanalaisten eläinten.., 2001). This difference may be explained in terms of the considerably smaller efforts put into the entomological studies in Karelia in comparison with those in Finland.

The history of the study of insect fauna in the present-day territory of Russian Karelia began some 150 years ago. Most of the known records were collected prior 1950. The first really important contributions to study of Karelian entomofauna were made in the second half of nineteenth century by the Finnish entomologists J.Sahlberg (1866), J.M.J.Tengström (1869), A.Westerlund (1892), B.Poppius (1899) and others as well as by a resident of Petrozavodsk, A.Günther (1868, 1896 a, b).

During the first half of the twentieth century detailedremarkable faunisticentomological studies of several groups of insects were made in the former Finnish territories located in the western part of Karelia in *Kl* and *Ks* provinces (most importantly by Tiensuu 1933, 1935, Platonoff 1943, Krogerus 1938, Kerrich 1939) and in the southern provinces of *Kol* and *Kon* in territories occupied during the Second World War (Palmén & Platonoff 1943, Palmén 1946, Kaisila 1944, 1947, Peltonen 1947, Kontuniemi 1965). All the articles of that period concerning entomofaunistic studies in the present-day territory of Karelia were recently surveyed recently by Pekkarinen & Huldén (1995). Faunistic records of several some groups of aquatic insects collected by the participants of the Olonetz Scientific Expedition (1919–1924) were published as well (Djakonov 1922, Martynov 1928, Lepneva 1928). Thison the data on water dwelling invertebrates was later summarised in a monograph on the fauna (invertebrates) of the lakes of Karelia which incorporated a set of articles concerning various insect groups (Fauna of Karelian lakes.., 1965).

Unfortunately the present authors are not aware of the whereabouts of insect collections made before 1950. We only possess materials obtained after 1950 when In the end of 1940s the first a research group on forest pathology was established in the Forest Research Institute of the Karelian branch of the USSR Academy of Sciences. The group's four researchers Vladimir Shiperovich, Boris Yakovlev, Evelina Titova and Irina Volkova focused This group has carried out on ecological studies of those insects which damage the seedlings of conifers in the vast clear-fell areas of southern Karelia. During that period studies were mostly carried out in the surroundings of Petrozavodsk near the villages of Matrosy, Prjazha and Lososinnoje (1950–1954), Nelgomozero (1955–64) and Pedaselga (1969–72). Comprehensive data was collected concerning insect pests affecting young stands in clearings (Shiperovich & Yakovlev 1957; Titova, 1959) as well as insects which damaged spruce cones (Yakovlev, 1961). On the other hand, the data from this period on insects inhabiting old growth forests iswere comprehensively covered by the work of Shiperovich (1949) who surveyed potential insect pests in the old growth forests of the Kivach Nature Reserve. This topic initiative was further developed in the 1980–90s by the joint research team of the Karelian Forest Research Institute and Moscow Forest University (Yakovlev & Mozolevskaja (eds.), 1991; Humala, 1995; Yakovlev, 1996; Yakovlev et al, 2001a).

Since the 1980s entomological studies have increasingly focused on the fauna of various insect groups throughout the whole of Karelia. Several expeditions to areas in Karelia which had not previously been studied in detail have been conducted and extensive material has been collected. At the present time they are published only in part (Yakovlev et al., 1995, 1999, 2000b, Siitonen et al., 1996; Martikainen et al., 1996; Lindholm et al. (eds.), 1997; Humala & Polevoi, 1999; Kolström & Leinonen (eds.), 2000). The present paper is an attempt to sum up available data on the number of species of insects in different biogeographical provinces in Karelia and the distribution of rare and endangered species.

Study areas. The areas covered by entomological studies carried out during 1950–2000 are shown on the map (Fig. 53). The names and boundaries of the biogeographical provinces are given after Heikinheimo & Raatikainen (1971).

1. ***Karelia ladogensis* (*Kl*) –** Environs of Sortavala: Riekkalansaari, Havus, Kotiluoto, Putsaari, Heytinsaari and Mäkisalo Islands in Lake Ladoga and the adjacent part of the mainland formed by the shores of Kirjavalahti and Impilahti bays (1994, 1997); Puikkola and the western shore of Lake Janisjärvi (1991); Lahdenpohja district: Huhojämäki, Ihala, Kurkijoki (1976, 1981); Pitkäranta district: Salmi, Karku (1981, 1992, 1994), Nizhneswirsky State Nature Reserve (1992).

2. ***Karelia olonetsensis* (*Kol*) –** Pryazha region: Kindasovo, Matrosy (1997–1999); Olonets region: Vidlitsa, Yurgelitsa, Megrega; Leningrad oblast: Gumbaritsy, Kovkenitsy, Kut-lahta (1992, 1994).

3. ***Karelia onegensis (Kon)*** – Kivach Nature Reserve (1985–2000), Konchozero, Gomselga;

Zaonezhsky Peninsula: Shunga, Tolvuja and Zharnikovo, Lake Kopanets, Lake Kosmozero and Svyatukha Bay in Lake Onega; Kizhi Archipelago: Kizhi, Bolshoi Klimenetsky, Volkostrov and Yuzhny Oleny Islands (1994–2000).

4. ***Karelia transonegensis* (*Kton*) –** Vodlozerskyo National Park (1992, 1995, 2001); Besov Nos (1995); Ust-Reka (1996), Kubovo, Bochilovo, Pyalma and Tuba (1996, 2000).

5. ***Karelia borealis* (*Kb*) –** Tolvajärvi Landscape Reserve (1992, 1993, 1999)

6. ***Karelia pomorica occidentalis* (*Kpoc*) –** Proposed Kalevala National Park (1996–1998); Kostomuksha Nature Reserve (1993–2000); proposed Tuulos Natural Park (1994); Lake Maslozero area: Jukkoguba, Lake Palosjärvi, Lake Kuzhjärvi and Nesterov Fjell (2000).

7. ***Karelia keretina* (*Kk*) –** White Sea coast: northern shore of Chupa Bay, Kartesh Cape, Sidorov, Keret and Bolshoi Gorely Islands (1996, 1998); north-eastern part of Paanajärvi National Park and adjacent areas near Lake Tsipringa (1998, 2000).

8. ***Regio kuusamoensis* (*Ks*) –** Paanajärvi National Park (1998–2000), Nuorunen Fjell (1990) and the River Tavanga (1993).

Insect collection methods. We studied the species composition of insects using the following methods: (1) trapping actively flying insects with Light-weight Malaise traps and window traps; (2) hand picking insects under the bark of dead trees and on the fruit bodies of wood-growing fungi (3) sweep-netting with a standard entomological net. Collected insect samples were pre-sorted, then specimens were pined or kept in 70% alcohol for further treatment. Collections are stored at the Forest Research Institute, KRC, RAS (Petrozavodsk), and at the Moscow Forest University.

Results. Insect fauna: assessment of present knowledge. In Table 25 we attempt to summarise all suitable records of the insect orders Coleoptera, Diptera Hymenoptera and Lepidoptera taken in Russian Karelia after 1950. These records are collected from three sources: (1) the authors' own collections, (2) published material and (3) unpublished or partly published information relating to entomological excursions by Finnish entomologists during 1992–1993 (Ilpo Mannerkoski, Lauri Kaila, Petri Martikainen & Juha Siitonen, pers.meds).

From the geographical perspective the study of Karelian insect fauna since 1950 has been is unsystematic and incompletein geographical aspect. Most records obtained after 1950 originate from the southern part of Karelia (*Kon* and *Kol* provinces) and in every province faunistic records of insects are the result of studies of only relatively small specific areas.

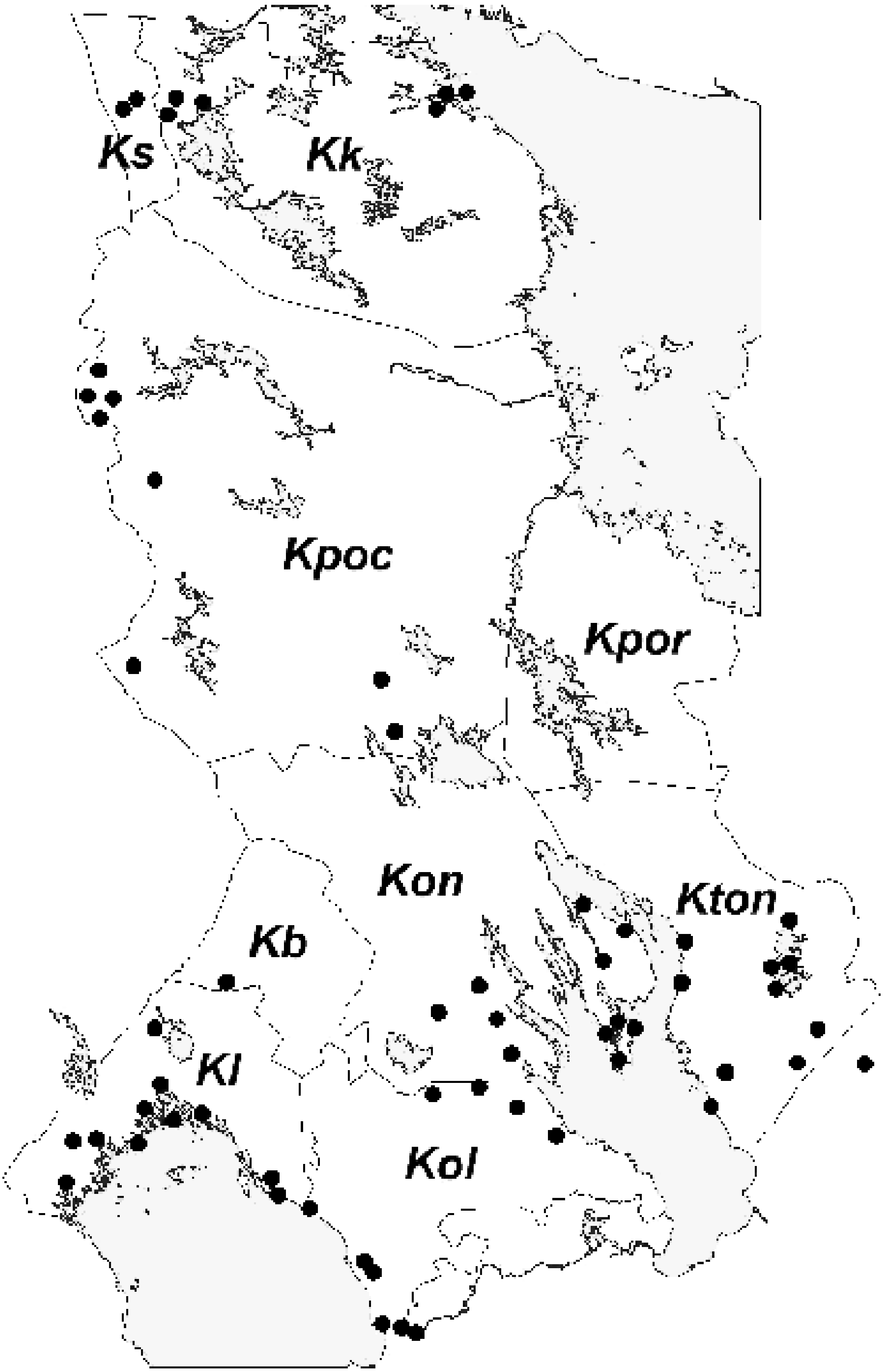

Figure 53. Insect sampling sites in Karelia (1950–2000)

Table 25

Number of species of Coleoptera, Diptera and Hymenoptera recorded during 1950-2001 in the various biogeographical provinces of Karelia

Orders of insects	*Whole territory*	*Ks*	*Kpoc*			*Kk*	*Kon*		*Kol*	*Kl*
		Paanajärvi NP	Kalevala NP	Kostomuksha nat.res	Maslozero	White Sea	Zaonezhye	Kivach nat.res.		
Coleoptera	1178	161	179	342	63	40	158	771	323	194
Diptera	1493	281	248	151	124	230	391	952	167	200
Hymenoptera	739	42	51	32	38	60	91	435	111	117
Lepidoptera	1194	–	–	274	–	–	–	777	–	–

Karelia onegensis (Kon). Most of the valid insect records made in Karelia since 1950 originate from this province. The areas best studied during the past two decades are Kivach Nature Reserve and Zaonezhsky Peninsula, both of which are situated in south-east part of the province. Both areas are covered with secondary deciduous forests containing extensive stands of aspen growing on the fertile soils of abandoned agricultural lands along with well preserved and fairly large fragments of old growth coniferous forest. This combination has resulted in a very high diversity of insect species. Some of the faunistic data on Coleoptera, Diptera, Hymenoptera and Lepidoptera from this province has been published elsewhere (Yakovlev & Uzenbaev (eds.), 1986; Kutenkova, 1989; Yakovlev & Mozolevskaya (eds.), 1991; Kaila et al., 1994; Yakovlev, 1996; Yakovlev et al., 1999, 2000a; Kravchenko et al. (eds.), 1997).

***Karelia olonetsensis* (*Kol*)**. Detailed studies on the insect fauna, especially Coleoptera (Palmén & Platonoff 1943, Palmén 1946) and Lepidoptera (Kaisila, 1947), were conducted during the 1940s in the southernmost part of the province, i.e. the Olonets region and the environs of the River Swir. Few studies have been carried out since 1950 and little material exists as a result. However, we do possess some faunistic data from several regions within this province. From the 1950s up until the present day collections have been made in the area around Petrozavodsk (Sainavolok, Lososinnoje, Mashezero) and Prjazha region (Yakovlev & Uzenbajev, eds., 1986). Between 6th and 9th July 1992 during a summer excursion of the Entomological Society of Finland insects were collected by a large group of entomologists in the Olonets region (Vidlitsa, Yurgelitsa and Megrega) and in adjacent areas of Leningrad province (Nizhneswirsky Nature Reserve). As a resulted of this expedition new lists of endangered species were published (Siitonen et al., 1996) and preliminary records of Coleoptera, Diptera and Hymenoptera species were also taken (Ilpo Mannerkoski, pers.med). In Prjazha region, close to the villages of Matrosy and Kindasovo, faunistic studies of forest Coleoptera were undertaken during 1954-55 and again during 1997–1999. Preliminary data concerning significant beetle species associated with dead wood and fungi have been published (Kolström & Leinonen, eds. 2000) although a comprehensive species list is still lacking. Data on Diptera and Hymenoptera has been obtained from short-term Malaise trapping and sweep netting in Matrosy, Kindasovo and Kaskesnavolok.

***Karelia ladogensis* (*Kl*).** Most of the existing data from the northern shores of Lake Ladoga was recorded in the first half of the 20th century. Recent studies (Martikainen, Niemela, 2000; Yakovlev et al., 2000a; Weidow, 2000) have produced relatively little data. Only a small number of insect collections was performed on the northern and eastern shores of Lake Ladoga during the 1990s and in Lahdenpohja district during the 1970s-80s. Some collections have been recently taken (1992, 1994) in eastern shores of Lake Ladoga (villages Salmi and Karku) during mutual excursions of Finnish and Russian entomologists. In 1991 seasonal window trapping was performed in secondary birch-dominated forests growing on abandoned agricultural lands near the village of Puikkola and in the fragments of old growth spruce forests on the western shore of Lake Janisjärvi. To date only a small part of this material has been published (Yakovlev, 1996; Martikainen et al, 1998).

The southernmost part of the province *Kol* (Olonets region and adjacent part of Leningrad province) was well-studied during the war time (Platonoff, 1938; Palmen, 1946), but data obtained after them are almost absent. The same situation should be observed in the province *Kl*. Most of the known data from northern shores of Ladoga Lake were reported in the first half of the XX century, while the recent data (Martikainen et al, 1998; Martikainen, Niemelä, 2000; Yakovlev et al., 2000a; Weidow, 2000) are very scanty.

Before the end of 1990s very little was known of the insects in the ***Karelia pomorica occidentalis* (*Kpoc*)** province which covers extensive territories in mid and northern Karelia. Only a few records of butterflies (Kaisila, 1944; Peltonen, 1947) and sawflies (Kontuniemi, 1965) were known from these areas. Some other war-time records of insect species from the areas lying along the Medvezhyegorsk—Segezha railway could be found in Finnish entomological journals. However, over the past few years the insect fauna of these provinces has been actively studied. Numerous records concerning several insect groups were taken from Kostomuksha Nature Reserve (Lindholm, et al., (eds.), 1997) and from the territory of the proposed Kalevala National Park (Yakovlev et al., 2000b). Some faunistic data has been collected during short-term expeditions into the surroundings of Lake Maslozero (Yakovlev et al., 2001b). However, such data represents only a superficial survey of the entomofauna of this vast area.

Quite recently large scale entomological investigations were also carried out in ***Karelia borealis*** near the Finnish-Russian border in the territory of the proposed Koitajoki-Tolvajärvi Reserve (Siitonen et al., 1995, 1996; Martikainen et al., 1996) and in adjacent areas of Finland (Hokkanen & Ieshko, eds., 1995; Hokkanen (ed.), 2001).

In the northernmost part of the Karelian Republic the only well studied area is that around Lake Paanajärvi located on the border of the provinces of ***Regio kuusamoensis*** (***Ks***) *Ks* and ***Karelia keretina*** (***Kk***)*Kk*. Before the 1940s a number of expeditions to this area was undertaken by Finnish entomologists (Viramo, 1998). Comprehensive reviews concerning several insect groups were published by Platonoff (1943) and Krogerus (1938). In all, 1782 insect species were reported from Paanajärvi (Viramo, in press.). Our own studies have brought the total up to 2006 species (Yakovlev et al., 2000b). Besides the shores of Lake Paanajärvi we conducted studies in the eastern part of the territory of Paanajärvi National park together with the adjacent unprotected areas along the northern bank of the River Olanga which is covered by old growth pine forests on sandy soils. For ***Karelia keretina*** we also possess data concerning Diptera, Hymenoptera (Humala & Polevoi, 1999) and Lepidoptera (Swiridow, 1970) collected in the White Sea coastal area.

The two large provinces ***Karelia pomorica orientalis*** and ***Karelia transonegensis*** situated to the north and east of Lake Onega remain more or less unstudied. Only a few records resulting from short term expeditions are extant from Vodlozerskyo NatNational park and adjacent areas (Siitonen et al., 1996; Polevoi, 2000) while unpublished data from other areas is scant.

Study of Karelian entomofauna is also uneven in systematic terms. Faunistic records after 1950 mostly concern three four large insect orders, namely Coleoptera, Diptera, and Hymenoptera and Lepidoptera. Almost all available data on other insect orders is based on old material collected before 1950.

Coleoptera seems to be the best studied group in Karelia. According to Silfverberg (1992) the number of species reported from Russian Karelia including the Karelian Isthmus is 2446. However the bulk of the data including comprehensive studies of Poppius (1899), Platonoff (1938, 1943), Palmén & Platonoff (1943) and Palmén (1946) was recorded prior to 1950 and neither the collection of the Karelian Scientific Centre or of any other scientific organisation in Karelia includes material from that period. Data concerning some 218 species of aquatic beetles found in various lakes in Russian Karelia during the 1950s was published by Sergei Gerd (Fauna of Karelian lakes.., 1965) but these materials are not presented in our collections as well. All valid records of terrestrial Coleoptera (Carabidae, Curculionidae and several saproxylic groups) taken in Karelia during the period 1950–1985 were summarised in Yakovlev & Uzenbajev, eds. (1986). Over the last two decades a long term study of saproxylic Coleoptera has been performed in Kivach Nature Reserve. This has produced a great deal of material although to date only a small fraction of this has been treated and published (Yakovlev & Mozolevskaya, eds., 1991, Kaila et al., 1994, Yakovlev, 1996). Recent studies of saproxylic Coleoptera in northern Karelia (Yakovlev et al. 2000b) revealed 52 species which had not previously been recorded from the Paanajärvi area. Over the last decade several new records of Coleoptera from the southern part of Karelia have been obtained by Finnish entomologists (Siitonen & Martikainen, 1994; Siitonen et al., 1996; Martikainen et al., 1996, 1998).

By contrast, old material on Karelian Diptera is minimal while over recent years several groups of flies have been intensively studied. These include various blood-sucking families: Simulidae (Usova, 1961), Ceratopogonidae (Glukhova, 1962), Tabanidae (Lutta, 1970) and some groups with water-dwelling larvae (Fauna of Karelian lakes.., 1965), along with groups associated with fungi and dead wood (Yakovlev, 1993, 1994, 1995; Yakovlev, Uzenbajev, eds., 1986; Yakovlev & Myttus, 1990; Yakovlev & Mozolevskaya, eds, 1991; Kravchenko et al., eds., 1997; Polevoi, 2000). The number of species of the fungus gnats Bolitophilidae, Ditomyiidae, Keroplatidae, Diadocidiidae and Mycetophilidae (616 species from 71 genera) recorded in Russian Karelia during intensive studies over a period of some twenty years (1977–2000) seems particularly high. Indeed, it represents about the half of the entire species pool of these insects in the Palearctic (1211 species from 99 genera). The long-term trapping of fungus gnats in differing forest habitats has, together with breeding experiments (Yakovlev, 1994, 1995; Polevoi, 2000), has revealed the habitat preferences of the most prolific species, the patterns of their seasonal activity and the discovery of previously unknown fungal hosts for many species.

Over the last decade numerous faunistic records of Hymenoptera, particularly aculeate and parasitoid groups, have also been published (Yakovlev & Tobias, 1992; Humala, 1997a, 1997b; Humala & Polevoi, 1999, etc.).

Lepidoptera since 1950 have been studied in detail at only three localities, i.e. Kivach Nature Reserve (Kozlov, 1983; Kutenkova, 1989), Kostomuksha Nature Reserve (Lindholm et al. (eds.), 1997) and the Kandalaksha region on the White Sea coast (Swiridow, 1970) which actually belongs to the Murmansk district. In total 1194 species are recorded.

Thus, in entomofaunistic terms Karelia has ceased to be a white patch on the map of Fennoscandia. It is especially important that we still possess data reflecting the state of Karelian insect fauna before intensive forestry technologies were applied and semi-natural unmanaged forests became in some way altered.

Findings of rare and vulnerable insects. Biotic diversity in natural forest ecosystems can be most precisely characterised by the species composition of organisms dominating in terms of number of species occurring and the variety of ecological niches exploited, as well as by the degree to which species are sensitive to environmental changes caused by human activities. Saproxylic insects defined by Speight (1989) as «species that are dependent, during some part of their life cycle, upon the dead or dying wood of moribund or dead trees (standing or fallen), or upon wood-inhabiting fungi, or upon the presence of other saproxylics» have proven to be one of the best indicator groups for the conservation value of forest habitats. Population changes of endangered species of saproxylic insects may be used to assess the effect of forest management methods, particularly with respect to various types of felling, on the biodiversity of forest ecosystems. Of all forest insect species the most prolific saproxylic insects comprise three orders, i.e. Coleoptera, Diptera and Hymenoptera (Siitonen, 2001). Although this was calculated only for Finland it is probably equally valid for Russian Karelia.

Over the past fifty years Karelian forests have been subject to profound transformation. The southern part of Karelia has been thoroughly transformed after large scale forest felling, especially between the 1940s and 1970s. Natural coniferous forests have had been gradually replaced by mixed forests containing an increased proportion of deciduous trees (Tab. 26). Between 1988 and 1998 the proportion of deciduous-dominated forests in the whole Republic remained more or less constant (10.7–11%). According to present demarcation of Karelian territory as used in forest inventories the proportion of birch and aspen dominated forests is, on average, 10.8% in the western region, 16.5% in the eastern region and 23.5% in the southern region. The northern part of Karelia is characterised by lower proportion of mixed forests (6.9% in the central region and 3.3% in the northern region).

Table 26

Total forest covered land in five regions of the Republic of Karelia, species constitution and age structure of forests in 1988–1998*

Region of Karelia	Forest covered land / 1000 hectares	Species constitution of forests / %				Age structure of forests / %			
		Pine	Spruce	Birch	Aspen	0–40 yrs	40–80 yrs	80–120 yrs	> 120 yrs
North	2493.9	76.1	20.6	3.3	0	32.7	13.5	6.9	46.9
Central	2447.3	77.6	15.6	6.8	0.1	53.7	14.2	3.1	29
Western	1140.6	62	27.2	9.7	1.1	33.4	27.8	16.3	22.5
Southern	2011.1	42.5	34	20.2	3.3	38.1	30.4	10.3	21.2
Eastern	872.7	29.8	52.8	16.4	1	24.9	18.9	5	51.2
TOTAL, 1988	8965.6	62.6	26.2	10.1	1.1	39	19.9	7.6	33.5
TOTAL, 1993	8983.3	63.7	25.6	10	0.7	38.5	21.2	7.6	32.6
TOTAL, 1998	9267.4	63.8	25.2	10.1	0.9	38	22	7.8	32.2

* 1988 – Forest inventory data from 01.01.1988; 1993 and 1998 – State report … (1998).

The age structures of forests have also been transformed. Mature forests of 120 years and more make up only about 20–30% of the total forest cover in the southern, western and central regions. The corresponding figures for the eastern the northern region are 51% and 46.9% % respectively. These include the vast areas of almost untouched natural coniferous forests situated in existing and proposed protected territories

Available data from the post-war period on the occurrence of rare and endangered insect species may be found in the Red Data Book of Republic of Karelia (1995), Red Data Book of East Fennoscandia (1998) and one or two other publications (Aarnio & Ojalainen, 1995; Yakovlev et al., 1995; Polevoi & Ståhls, 1995; Siitonen et al., 1996; Humala, 1998). Many records of endangered insects have been made as recently as 1995–2001 and are therefore not included in the current editions of the Red Book of Republic of Karelia (1995) and East Fennoscandia (1998). Indeed we are unable to mark out the distribution areas of these species owing to the lack of information from the unstudied areas. However, available data (Table 27) allows us to draw some conclusions regarding the distribution of rare and endangered insects in Karelia.

In spite of the fact that most Karelian forests still remain unmanaged we found a decline in several species of Coleoptera associated exclusively with pine, namely, *Chalcophora mariana* (Buprestidae), *Boros schneideri* (Boridae), *Tragosoma depsarium* (Cerambycidae), *Orthotomicus longicollis,* and *Ips sexdentatus* (Scolytidae). In the early 1950s these species were collected in and around fresh clear-fell areas throughout southern Karelia. However, by 1990–2000 they were restricted to protected areas such as the Kivach and Nizhnesvirskii nature reserves. In southern Karelia all of these have become very rare due, most probably, to the demise of old growth pine forests in the area. In more northerly areas where vast fragments of untouched pine forests still survive only *Boros schneideri* remains common while *Ips sexdentatus* may be found in piles of unbarked pine logs. The drastic decline of pine-dominated forests in southern Karelia will in all likelihood lead to the gradual extinction of these species.

Several Coleoptera species associated with spruce, i.e. *Pytho kolwensis*, *P. abieticola* (Pythidae) and *Ditylus laevis* (Oedemeridae), also require conditions which pertain only in minimally transformed taiga forests. Our data does not show any decrease in the prolificacy of these species with *Ditylis laevis* appearing to be naturally rare in any case. Luckily these species inhabit paludified spruce forests which generally escape felling due to their low timber quality. The longhorn beetle *Monochamus urussovi* (Cerambycidae) which develops on large, recently deceased spruce trees used to be common in Karelia, especially in burnt-over areas. Today, however, this species is significantly less prolific while the closely related species *Monochamus sutor* remains very common.

Insects associated with deciduous trees have not, in general, become rarer in Karelia during the course of the 20th century. This is in contrast to the situation in Finland and other Scandinavian countries where the proportion of deciduous-dominated forests has sharply decreased as a result of intense management. In Russian Karelia, especially in its southern part, we find quite the opposite trend in changes to the forest structure (cf. Table 26). Thanks to the con-

Table 27

Findings of rare, endangered and various other saproxylic insect species restricted to the minimally transformed forests of Russian Karelia during 1950–2001

Insect species	*Kl*	*Kol*	*Kon*	*Kton*	*Kb*	*Kpoc*	*Kpor*	*Ks*	*Kk*	Status in Red Data Book	
										Karelia	Finland
Coleoptera											
Trachypachus zetterstedti (Gyll.)	1	+	1							–	V
**Agathidium pallidum* (Gyll.)	1		1							4	3
**Phymatura brevicollis* (Kraatz)	1									–	V
**Cyphea latiuscula* (Sjob.)				1						–	M
**Batrisodes venustus* (Reich.)			1							–	M
Oxyporus mannerheimii Gyll.		1	1							3	4
**Acritus minutus* (Herbst)			1	1						4	V
Hololepta plana (Sulz.)		1	1							2	E
Ceruchus chrysomelinus Hoch.		1	1	1	1					4	V
Sinodendron cylindricum L.		1	1							3	–
Platycerus caraboides (L.)			1							4	M
Liocola marmorata (Fabr.)		1	1							3	M
Lacon conspersus (Gyll.)		1	1		1	1	1				
Lacon fasciatus (L.)		+	1		1					4	M
Ampedus praeustus F.		+	1							–	M
Ampedus cinnabarinus (Esch.)		+	1	1						4	M
Ampedus nigroflavus (Goeze)				1						–	M
**Ampedus suecicus* Palm	1			1	1					–	V
Hylochares cruentatus (Gyll.)		+	1	1						2	H
**Dirrhagofarsus attenuatus* (Makl.)				1						–	E
Chalcophora mariana L.		1	2							1	H
Buprestis novemmaculata L.		2								3	M
Buprestis octoguttata L.	1	+								3	–
Dicerca alni (Fisch.)		1	1							4	M
Melanophila acuminata (Deg.)		2	2							4	M
Melanophila cyanea F.		1	1					1		3	M
**Agrilus ater* (L.)			1							–	E
Globicornis corticalis (Eich.)			1							4	M
* *Stephanopachys substriatus* (Payk.)					1					–	E
* *Stephanopachys linearis* (Kug.)					1					–	E
Calitys scabra (Thunb.)		+	1		1					4	M
Peltis grossa (L.)	1	1	1	1	1	1				4	M
Cyllodes ater Hbst.		1	1	1	1					2	E
Rhizophagus puncticollis Sahlberg		1	1							2	H
**Cucujus cinnaberinus* (Scop.)		+		1						2	E
Silvanus unidentatus (Ol.)	1	+	1	1						4	M
**Uleiota planata* (L.)		1		1						2	E
Triplax rufipes (F.)	1	1	1		1					4	M
Cerylon impressum Erich.			1	1						–	M
Cis fissicornis Mellie		1	1	1						–	M
**Sulcacis fronticornis* (Panz.)		1								–	M
Sulcacis bidentulus (Ros.*)*		+		1						–	–
Wagaicis wagai (Wank.)			1	1						–	V
Mycetophagus quadripustulatus L.	1	1	1		1					4	M
Ditylus laevis F.		–	1							2	V
Pytho kolwensis Sahlb.		1	1	1	1	1		1		4	V
Boros schneideri Pz.			1	1	1	1		1	1	2	V
Scotodes annulatus Esch.	1	+	1							4	V
Upis ceramboides (L.)		1	1	1	1	1				–	–
**Corticeus longulus* (Gyll.)				1						–	M
Corticeus fraxini (Kug.)			1	1		1				4	M
Mycetochara humeralis (F.)		+	1							4	M
Tomoxia bucephala Costa	1	1	1	1						4	M
Dircaea quadriguttata (Payk.)		+	1	1						3	V
Zilora elongata J.Sahlb.			1							–	–
Serropalpus barbatus Schall.		1	1							–	–
Stenotrachelus aeneus Payk.		+	1			1				–	–
Melandrya dubia Schall.	1	1	1	1	1	1		1	1	4	M
Phryganophilus ruficollis F.	1	1	1							2	E
Xylita livida (Sahlb.)		1	1							4	–

Insect species	*Kl*	*Kol*	*Kon*	*Kton*	*Kb*	*Kpoc*	*Kpor*	*Ks*	*Kk*	Status in Red Data Book	
										Karelia	Finland
Tragosoma depsarium L.		2	1	1	1	+				2	V
Pachyta lamed (L.)		+	2							–	–
Pachyta guadrimaculata L.		1	1							–	–
Evodinus borealis (Gyll.)		1	1		1			1		4	–
Acmaeops septemtrionis (Thoms.)			1		1	1				4	E
**Cortodera femorata* (F.)			+								
**Nivellia extensa* (Gebl.)								+		–	–
Nivellia sanguinosa (Gyll.)			1							4	M
Anoplodera variicornis (Dalman)			1							3	–
Leptura nigripes Deg.	1	1	1	1	1	+				4	M
**Leptura pubescens* F.	+		+							3	V
Leptura thoracica Creutz.	1	1	1							2	E
Aromia moschata L.	1	1	1			+				3	–
**Obrium brunneum* (F.)	+									3	–
**Obrium cantharinum* (L.)	+	+	+							4	–
Necydalis major L.	1	1	1					1		4	–
**Semanotus undatus* L.	+	+	+			+		+		4	M
Monochamus urussovi (Fisch. v.Wald.)	2	2	1	1	1	2	2			4	V
Acanthocinus griseus F.	1	2	1	1		+	+			4	M
Saperda carcharias L.	1	1	1	1		1				–	–
Saperda perforata Pall.	1	1	1	1		+				4	M
Oberea oculata L.	+	1	1							3	–
Phytoecia nigricornis F.	+	+	1							–	M
Platyrhinus resinosus (Scop.)	1	+	1							4	V
Tropideres dorsalis Thunb.		1	1							4	M
Cossonus parallelepipedus Hbst.		+	1							2	E
Cossonus cylindricus Sahlb.		1	1	1						2	E
Hylobius sibiricus Egorov								1		–	–
Orthotomicus longicollis (Gyll.)			1	1						2	V
Ips amitinus Eich.	2	1	1	1	1			1	1	–	–
Ips sexdentatus (Borner)	2	2	1			1				–	–
Trypodendron laeve Eggers								1		–	–
Trypophloeus bispinulus Egg.			1					1		–	–
Xyleborus cryptographus (Ratz.)		1	1							4	V
Diptera											
Pachyneura fasciata Zett.		+	1	1	1					4	V
Keroplatus tipuloides Bosc	1	1	1		1					4	V
Xylophagus ater Mg.	1		1	1	1					4	V
Xylophagus junki Szilady		+	1	1	1					4	V
Xylophagus matsumurae Miyat.			1			1				–	–
Laphria gibbosus L.		1	1							–	–
Xylomya czekanovskii (Pleske)	1	1	1	1	1					2	E
Hemipenthes maurus L.	1	1		1						–	–
Sphegina clunipes Mg.			1		1	1			1	4	M
Sphegina sibirica Stack.			1	1	1	1		1		–	M
Spilomyia diophthalma L.	1	1	1	1	1					4	M
Temnostoma vespiforme (L.)	1	1	1	1	1				1	–	M
Temnostoma apiforme F.	1	1	1	1	1					–	M
Temnostoma bombylans F.	1		1	1						–	M
Sphecomyia vespiformis Gorgski								1		–	V
Anomalochaeta guttipennis Zett.		+	+					+	1	–	M
Hendelia beckeri Czerny	1		1	1	1					4	M
Hymenoptera											
Pseudoclavellaria amerinae L.		2	1							4	H
**Ussurinus nobilis* Saar.		+	+							4	E
Monoctenus obscuratus (Htg.)		+	1							–	–
Sapyga similis (F.)	+							1	1	–	–
Vespa crabro L.	+	1	1	1						3	E
Ancistrocerus antilope (Pz.)	+	1	1					+		4	M
Symmorphus crassicornis (Pz.)	+		1							4	M
Symmorphus fuscipes (H.-Sch.)	1		1							4	M
Coelioxys lanceolata Nyl.	+		1						1	–	M
Bombus balteatus Dhlb.								1		–	–
Bombus humilis (Ill.)	+	+	1							–	–
Bombus lapponicus (F.)								1		–	–

Insect species	*Kl*	*Kol*	*Kon*	*Kton*	*Kb*	*Kpoc*	*Kpor*	*Ks*	*Kk*	Status in Red Data Book	
										Karelia	Finland
Bombus muscorum (F.)			1							4	M
Gasteruption assectator L.	1									–	–
Ibalia rufipes Cresson	1									–	–
Dolichomitus imperator Kriechb.	+	1	1		1	1				3	H
Neoxorides montanus Oehlke		1	1			1			1	–	–
Megarhyssa emarginatoria (Thunb.)	1	+	1							–	–
Coleocentrus exareolatus Kriechb.			1							4	–
Microleptus rectangulus (Thoms.)			1							3	–
Odontocolon spinipes Grav.	1		1			1				3	–
Xorides brachylabis Kriechb.						1		1	1	4	–
Adelognathus longithorax Kasp.	1									3	–
Seleucus cuneiformis Holmgr.			1		1					3	–
Megaplectes monticola Grav.	+		+						1	–	–
Oxytorus luridator Holmgr.	+		1							–	–
Metopius anxius Wesm.									1	–	–
Spudaeus scaber Grav.			1		1	1				3	–
Protichneumon coqueberti Wesm.			1							–	–
Trogus lapidator (F.)		2	1			1		+	1	3	M

Records from 1975–2001; 2) records from 1950-1975; «+» old records (before 1950). Species marked with an asterisk (*) are not represented in our collections. The status of red-listed species accords with the national Red Books of Finland (Uhanalaisten eläinten.., 1992) and Karelia (1995).

tinuous availability of the dead wood of deciduous trees, particularly aspen, a number of insect species which have become extinct (*Hylochares cruentatus*, *Rhizophagus puncticollis)* or endangered (*Agathidium pallidum*, *Hololepta plana, Cyllodes ater, Tomoxia bucephala, Leptura thoracica*, *Cossonus cylindricus, C. parallelepipedus, Xylomya czekanovskii)* in Finland are still common in Russian Karelia. This has been clearly demonstrated by Finnish entomologists (Siitonen & Martikainen, 1994, Siitonen et al., 1996) and is confirmed by our data.

Available data does not allow us to trace the population changes of insect species known to be typical inhabitants of burned forest areas and which require newly burnt trees for their larval development. The decline of these species due to the prevention of forest fires in Finland is evident. Thus, the forests of Karelia which are still frequently subject to forest fires provide the only refuge for fire-dependent species in the whole Fennoscandia. A study of insect communities in burnt areas of different ages would undoubtedly provide much valuable information.

The same may be noted concerning the studies of insect communities forming naturally in windfall forest areas following storms and tornadoes. At the end of June 2000 a tornado formed over semi-natural spruce-dominated forests on the eastern shore of Lake Vodlozero and caused a huge area of windfall extending over some 600 hectares. Since the area lies within Vodlozer National Park the fallen trees will most probably be left as they are, thus providing the opportunity to study the process of natural colonisation by saproxylic insects of large quantities of dead wood at varying stages of decay.

At least a half of the entire pool of insect species considered as rare or endangered in Karelia seem to occur only in its southern part. The number of both old and recent recordings of these species decreases sharply on moving northwards. In the relatively well studied central southern biogeographical provinces of *Kol* and *Kon* a range of insect species listed in the red data books has been recorded. Many of these have been also found during short-term studies in the south-eastern province of *Kton* and in *Kl.* in the south-west. The smaller number of endangered insect species collected in the provinces *Kb* and *Kpoc* cannot be explained in terms of less intensive study. Finally, Paanajärvi is situated well to the north of the distribution boundaries of many southern red-listed insect species in Karelia. This is especially evident for insects associated with deciduous trees, primarily aspen, willow and alder. In the Paanajärvi area we have found only *Necydalis major, Melandrya dubia* and *Trypophloeus bispinulus*. The same may be said about pine-associated beetle species. Several red-listed species such as *Chalcophora mariana, Tragosoma depsarium* and *Orthotomicus longicollis* have been found neither at Paanajärvi nor in the proposed Kalevala National Park in spite of the occurrence of extensive stands of old pine which have more or less escaped anthropogenic transformation. By contrast, the distribution areas of *Melanophila cyanea* and *Boros schneideri* appear to spread further north.

Thus, when discussing the development of a network of protected areas one should bear in mind the fact that the establishment of even very large reserves in northern Karelia is insufficient to guarantee the conservation of the biotic diversity of the boreal forests in Karelia. It is true that forests in northern Karelia survive in a more natural state than those further south. However, many species can only exist in the more fertile forests of the southern boreal zone. This applies to species associated not only with deciduous trees but also with conifers. Consequently, conservation efforts should also be directed towards the southern areas of Karelia. It is very likely that even small-sized key habitats could in sufficient numbers form a network capable of securing the viability of these species and thus maintaining natural biological diversity in the forest ecosystems of southern Karelia.

A large quantity of new data on rare and endangered insect species would make an important addition to the next edition of the Red Data Book of Republic of Karelia which, in any case, will comprise a monitorial report on the population trends of rare and endangered species following new IUCN criteria.

4. FLORA AND FAUNA OF AQUATIC ECOSYSTEMS: CHARACTERISTICS AND VARIATION TRENDS

4.1 Algal flora of lakes

Introduction. The aquatic ecosystems of Russian Karelia close to the Finnish border have not yet been affected by human activities. Available data for lake phytoplankton of the study area is sparse and fragmentary (Filimonova, 1965).

Phytoplankton is known to play a significant ecological role in aquatic ecosystems and some phytoplankton species are indicators of water quality (Algae. Handbook, 1989; Bibliographic guide: «Biological guide of water quality» with a list of contamination-indicating organisms, compiled by A.V. Makrushin 1974; All-purpose water quality assessment methods. Part III. Methods for biological analysis of water. Atlas of saprobic organisms, 1977). Thus, planktonic microalgae are an essential constituent of aquatic biota which may be used to diagnose early signs of anthropogenic changes in aquatic systems and which provide a valuable tool for environmental monitoring. It is therefore important to study lacustrine planktonic microalgae in the national parks to be established in Russian Karelia. These lakes may also used for reference purposes as they have been subject to only low levels of anthropogenic impact.

The goal of our project was to assess the predominant state of phytoplankton (species composition, prolificacy and biomass) in a large number of lakes of various types. The lakes selected were unaffected by commercial activities and mostly clean.

Study area and methods. In the summer (June-July) and autumn (September-October) periods of 1993–1999 a mapping study of lacustrine algal flora was conducted as part of a multi-disciplinary research project carried out by the Karelian Research Centre, RAS, in the proposed (Fig. 54) Kalevala Proposed National Park (lakes Sudnozero, Verkhneye, Sredneye and Nizhneye Ladvo, Srednyaya Vazha and Marya-Sheleka), Koitajoki Proposed National Park and Tolvajärvi Landscape Reserve (lakes Tolvajärvi, Jurikkajärvi, Saarijärvi, Ala-Tolvajärvi, Sayjunejärvi, Sonkusjärvi, Pieni-Kuohajärvi, Suuri-Kuohajärvi, Kangasjärvi and Kyljärvi), in Tuulos Proposed National Park (Lake Tuulos) and in some lakes on the Zaonezhye Peninsula (lakes Vandozero, Putkozero, Kosmozero, Yandomozero and Padmozero).

Phytoplankton samples were collected with a Ruttner sampler from depth of 0.5 metres in the pelagic part of lakes. These one litre phytoplankton samples were preserved in iodine-formalin solution (Kuzmin, 1975). After a settling period samples were condensed through membranous filters (pore diameter 0.95–1.02 μm). Cells were counted in a Nazhott-type chamber (volume 0.02 ml). Biomass was estimated by the volume-weight method, comparing the cell shape with a similar geometrical body (Kuzmin, 1984; Fedorov,1979). In order to describe phytoplankton ecologically and geographically we used the systems generally accepted in the ecology and biogeography of species (Bibliographic guide: «Biological guide of water quality» with a list of contamination-indicating organisms compiled by A.V. Makrushin, 1974; Proshkina-Lavrenko, 1953; All-purpose water quality assessment methods. Part III. Methods for biological analysis of water. Atlas of saprobic organisms. 1977; Hustedt, 1939; Sladecek,1973). The trophic status of lakes was assessed using relevant scales (Kitaev, 1984, Trifonova, 1990).

Results. In the ecosystems of Karelian cold-water lakes we discovered over 500 taxa of plankton algae. *Bacillariophyta*, *Chlorophyta* and *Chrysophyta* contribute most substantially to the diversity of phytoplankton (Chekryzheva, 1990). Also common in these lakes are *Cyanophyta, Cryptophyta, Dinophyta, Xanthophyta, Euglenophyta* and *Raphidophyta* algae (Chekryzheva, 1999).

Altogether 247 algal taxa (See Appendix) have been identified in the lake phytoplankton of the national parks studied. The structure of algal flora is shown in Table 28. Although each lake displays a phytoplankton pattern of its own, lacustrine algal flora comprises on average of *Bacillariophyta* (37%), *Chlorophyta* (29%) and *Chrysophyta* (14%). Other divisions are less common with *Cyanophyta* making up 10% and *Euglenophyta* 2%. Data presented in existing literature include similar figures for the aforementioned groups of phytoplankton in Arctic and tundra lakes (Aquatic flora and fauna in North Europe? 1978; Safonova, 1982). The above proportions of divisions are characteristic of planktonic algal flora in Northwest European Russia (Getsen, 1985; Letanskaya, 1974; Nikulina, 1975; Chekryzheva, 1990).

Kalevala Proposed National Park. In the pelagic zone of lakes 75 algal taxa from 8 systematic groups were recorded: *Cyanophyta* – 6, *Chrysophyta* – 13, *Bacillariophyta* – 28, *Xanthophyta* – 1, *Cryptophyta* – 2, *Dinophyta* – 5, *Euglenophyta* – 2, *Chlorophyta* – 17 and *Raphidophyta* – 1 (see Appendix). *Bacillariophyta*, *Chrysophyta* and *Chlorophyta* are the most widespread and account, respectively, for 38%, 17% and 23% of all algal taxa.

In the pelagic zones of lakes of different types the number of phytoplankton taxa found varies from 20 to 30 (Table 29). The diatoms *Tabellaria fenestrata* and *Tabellaria fenestrata var. intermedia* together with the dinophytic algae of the genus *Peridinium* make up 30–50% of total phytoplankton biomass and are considered to be the dominant

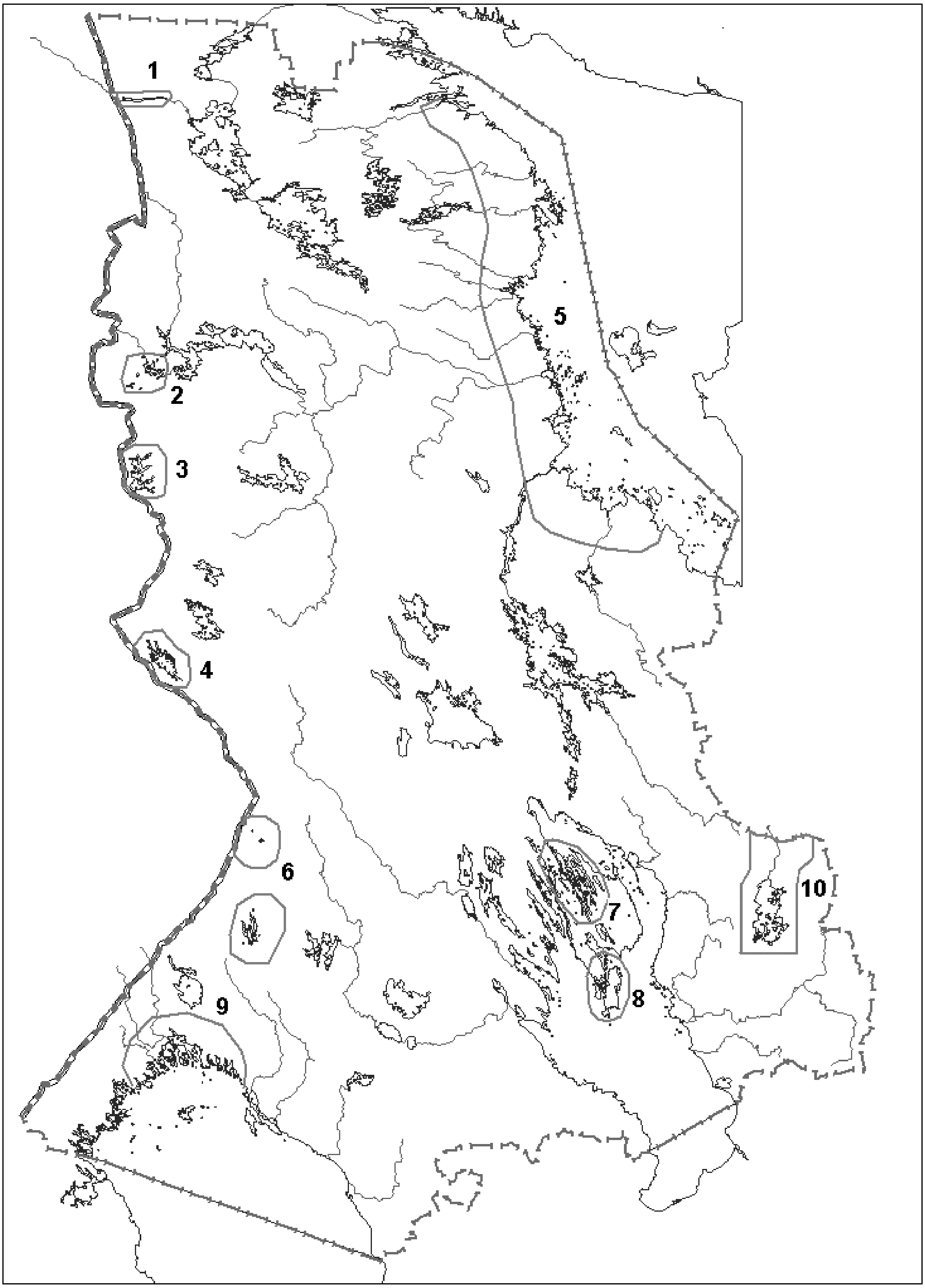

Fig. 54. Areas of hydrobiological studies

1 – Paanajärvi National Park (NP), 2 – Kalevala Proposed National Park (PNP), 3 – Kostomuksha Strict Nature Reserve, 4 – Tuulos PNP, 5 – rivers of Pomorian and Karelian Shores of the White Sea, 6 – Koitajoki PNP, 7 – lakes in Zaonezhye, 8 – Kizhi archipelago in the Onega lake, 9 – North skerries region of the Ladoga lake, 10 – Vodlozersky NP

Table 28

Taxonomic composition of phytoplankton in the lakes of the National Parks

Division	Number of taxa	% of total number of taxa
Cyanophyta	24	10
Chrysophyta	35	14
Bacillariophyta	92	37
Xanthophyta	2	1
Cryptophyta	7	3
Dinophyta	8	3
Euglenophyta	6	2
Chlorophyta	72	29
Raphidophyta	1	1
Total	247	100

taxa of Lake Sudnozero. Lakes Verkhneye and Sredneye Ladvo are dominated by Cyanophyta algae of the genus *Anabaena* which account for 30% of all phytoplankton, as well as Dinophyta algae (genus *Peridinium*) which make up a further 30% of total algal biomass. The alga *Gonyostomum semen* forms 35% in Lake Nizhneye Ladvo and contributes over 24% in terms of prolificacy and 80% to phytoplankton biomass in Lake Sredneye Vazha. Lake Marya-Sheleka is dominated with respect both to prolificacy and biomass by diatoms of the genus *Aulacoseira*.

Total prolificacy of phytoplankton varies from 70 000 to 1.5 million cells/l while biomass is 0.2–3.7 g/m^3 (Table 29). The highest biomass values (2 and 3.7 g/m^3) were recorded for lakes Nizhneye Ladvo and Sredneye Vazha, in which *Gonyostomum semen* grows vigorously.

Table 29

Number of taxa, prolificacy and biomass of phytoplankton in the lakes of Kalevala and Tuulos national parks

Lake	Number of taxa	Prolificacy (thousand cells/l)	Biomass (g/m^3)
Sudnozero	24	69	0.16
Verkhneye Ladvo	22	500	0.38
Sredneye Ladvo	28	800	0.71
Nizhneye Ladvo	31	1633	2.01
Marya-Sheleka	21	528	0.47
Sredneye Vazha	29	785	3.74
Tuulos	19	478	0.46

Analysis of the ecological and geographic characteristics of lake phytoplankton has shown that most of the taxa identified are widespread in land-locked water bodies. Biogeographically speaking, algal flora is dominated by ubiquitous species (85%) with northern-alpine (9%) and boreal (6%) species being far less common. With respect to their response to water salinity most species are oligohalobous; i.e. 86% of them are neither halophiles nor halophobes, 10% are halophobes and 4% halophiles. On the basis on their response to pH, indifferent species dominate (58%), acidophiles account for 27% and alkaliphiles 15%. Species indicative of saprobic lakes make up 50% of all algae, most of these (90%) being oligo-, oligo-b- or b-mesosaprobic.

Koitajoki Proposed National Park. A study of lake phytoplankton during the autumn revealed 179 algal taxa and varieties of 8 systematic divisions, thus: *Cyanophyta* – 16, *Chrysophyta* – 29, *Bacillariophyta* – 58, *Xantophyta* – 1, *Cryptophyta* – 6, *Dinophyta* – 8, *Euglenophyta* – 4 and *Chlorophyta* – 57 taxa (see Appendix). The largest contributions to the taxonomic diversity of lake phytoplankton are made by *Bacillariophyta* (33 %), *Chlorophyta* (32%) and *Chrysophyta* (29%) algae. In lakes Ala-Tolvajärvi, Saarijärvi and Yla-Tolvajärvi diatom taxa of the genera *Aulacoseira* and *Tabellaria* make up 40–50% of total phytoplankton biomass while the alga *Merismopedia sp.* (*Cyanophyta*) accounts for 50–60% of total prolificacy of phytoplankton. Lakes Jurikkajärvi and Sarsajärvi are dominated by the alga *Merismopedia spp*. (*Cyanophyta*) which constitutes 30–70% of total phytoplankton prolificacy in a range of lake biotopes, together with the alga *Chlamydomonas sp.* (*Chlorophyta*) which accounts for 17% of prolificacy and 40 % of total phytoplankton biomass. In Koitajoki National Park lake phytoplankton has a population density of 400–2380 thousand cells/l and a biomass of 0.2–1.0 g/m^3 (Table 30). Lakes Saarijärvi and Yla-Tolvajärvi are dominated in terms of both prolificacy and biomass by diatoms while lakes Ala-Tolvajärvi, Jurikkajärvi and Sarsajärvi are dominated with respect to prolificacy by small forms of *Cyanophyta* and in terms of biomass by *Bacillariophyta*.

In the algal flora of autumn plankton in Lake Saynejärvi diatoms are represented by species of the genera *Aulacoseira* (*A. islandica, A. italica var. tenuissima, A. subarctica, A. distans, A. ambigua*) and *Eunotia* (*E. robusta var. tetraodon, E. pectinalis var. ventralis, E. valida*) as well as *Tabellaria fenestrata, Asterionella formosa*, *Rhizosolenia eriensis* and *Tetracyclus lacustris*. *Chlorophyta* algal diversity encompasses the genera *Monoraphidium*

Table 30

Number of taxa, prolificacy and biomass of phytoplankton in the lakes of Koitajoki National Park

Lake	Number of taxa	Prolificacy (thousand cells/l)	Biomass (g/m^3)
Tolvajärvi	39	115	1.68
Jurikkajärvi	55	7	0.32
Saarijärvi	55	9	0.24
Julä-Tolvajärvi	32	7	0.20
Sarsajärvi	45	8	0.50
Ala-Tolvajärvi	94	9	0.44
Säynejärvi	35	361	0.45
Kangasjärvi	25	845	0.44
Kyläjärvi	28	180	0.19
Sonkusjärvi	15	130	0.05
Pieni-Kuohajärvi	26	68	0.02
Suuri-Kuohajärvi	25	633	0.16

(*M. mirabile, M. contortum, M. komarkova*) and *Chlamydomonas sp.* while *Cryptophyta* algae are represented by *Ñryptomonas sp.* and *Rhodomonas lacustris*. *Dinophyta* algae consist of *Peridinium sp.* and *Glenodinium sp. Chrysophyta* algae are represented by taxa of the genera *Chrysococcus* (*C. rufescens, C. punctiformis*) with *Stenokalyx* and *Kephyrion* also occurring. *Euglenophyta* present include taxa of the genera *Trachelomonas* and *Euglena* while the *Cyanophyta* algae *Merismopedia tenuissima* is also encountered. Phytoplankton is dominated terms of population size by *Chlorophyta* algae of the genus *Monoraphidium* (35–52%) and in biomass by *Gonyostomum semen* (*Raphidophyta)* (52%). Phytoplankton has an average population density of 361 000 cells/l and biomass of 0.45 g/m^3.

Plankton diversity in lakes Pieni-Kuohoajärvi, Sonkusjärvi and Suuri-Kuohoajärvi are mostly accounted for by *Bacillariophyta, Chlorophyta* and *Chrysophyta* algae (17–31, 33–45 and 15–40% respectively of the total number of taxa occurring). Lakes Pieni-Kuohoajärvi and Suuri-Kuohoajärvi are dominated in terms both of prolificacy and biomass by *Bacillariophyta* of the genus *Aulacoseira* as well as by *Tabellaria fenestrata* and *Tabellaria fenestrata var. intermedia*. Taxa of the genus *Dinobryon* (*Chrysophyta*) together with the alga *Merismopedia sp.* (*Cyanophyta*) account for a significant portion of prolificacy. Lake Sonkusjärvi is dominated by *Chlorophyta* algae (taxa of the genera *Planktococcus* and *Chlamydomonas*) which contribute over 70% to prolificacy and up to 40% to the biomass of total phytoplankton. A considerable contribution to biomass (up to 30%) is made by *Tabellaria fenestrata* (*Bacillariophyta*).

Population densities of phytoplankton in lakes Pieni-Kuohoajärvi, Sonkusjärvi and Suuri-Kuohoajärvi vary from 68 to 633 thousand cells/l with biomass estimated at 0.02–0.2 g/m^3 (Table 30). Maximum values occur in Lake Suuri-Kuohoajärvi.

The lakes of the Koitajoki River basin (Kangasjärvi and Kylajärvi) are dominated by *Bacillariophyta* (taxa of the genera *Aulacoseira* and *Tabellaria*) which make up the bulk of algae in terms both of prolificacy and biomass. They have average population densities of 180–845 thousand cells/l and biomass of 0.19–0.44 g/m^3.

Analysis of the ecological and geographic characteristics of lake phytoplankton has shown that most taxa identified are widespread in land-locked water bodies. Biogeographically speaking, algal flora is dominated by ubiquitous species while northern-alpine and boreal species are scarce. In terms of their response to salinity most species are oligohalobous; 80% are indifferent to water salinity while halophobous and halophilic algae are far less common. Response to pH indicates that the largest group consists of indifferent and acidophilic species. Species indicating saprobic lake type account for 50% of all algae. Most of these (90%) are oligo-, oligo-b- and b-mesosaprobes.

Tuulos Proposed National Park. The phytoplankton of Lake Tuulos consists of 19 algal species belonging to 7 systematic groups: *Cyanophyta* – 2, *Chrysophyta* – 5, *Bacillariophyta* – 6, *Cryptophyta* – 1, *Dinophyta* – 1, *Euglenophyta* – 1 and *Chlorophyta* – 3 taxa (see Appendix). *Bacillariophyta* (28%), *Chlorophyta* (24%) and *Chrysophyta* (20%) algae are the best represented. *Bacillariophyta* of the genus *Aulacoseira* and the *Cyanophyta* algae *Merismopedia sp.* dominate and account for some 30% of the overall prolificacy of phytoplankton.

The average population density of phytoplankton is 478 thousand cells/l with biomass at 0.46 g/m^3. Bacillariophyta (43%) and Cyanophyta algae (31%) are the most prolific. Dinophyta algae (40%) co-dominate with Bacillariophyta (50%). In both ecological and geographical terms the algal flora of plankton is characterised by highly varied taxa typical of freshwater lakes located at temperate latitudes.

Lakes in Zaonezhye. During the autumn 82 algal taxa and varieties from 6 systematic groups, i.e. *Cyanophyta* – 8, *Chrysophyta* – 7, **Bacillariophyta** – 42, *Dinophyta* – 1, *Euglenophyta* – 2 and *Chlorophyta* – 22 taxa (see Appendix), were identified in the pelagic and littoral zones of lakes. Bacillariophyta and *Chlorophyta* algae make up the most numerous taxa (51% and 27% of all taxa, respectively). *Chrysophyta* and *Cyanophyta* algae do not exceed 10%. Lake Putkozero has the smallest number of taxa (23). Lakes Padmozero and Kosmozero have 31 and 35 taxa, respectively, while lakes Vandozero and Yandomozero contain 40 and 41 taxa respectively. *Bacillariophyta* make up between 50 and 75% and *Chlorophyta* algae between 17 and 26% of all taxa. The *Bacillariophyta Tabellaria fenestrata, Fragilaria crotonensis* and

Asterionella formosa, together with taxa of the genus *Aulacoseira*, dominate in lakes Vandozero and Kosmozero. Lake Putkozero is dominated by the *Cyanophyta* alga *Planktotrix agarghii* and co-dominated by taxa of the genus *Aulacoseira*. The phytoplankton of Lake Padmozero is dominated in terms both of population density and biomass by *Bacillariophyta* of the genus *Aulacoseira*. In the pelagic zone of Lake Yandomozero *Microcystis aeruginosa* and *Anabaena lemmermanii (Cyanophyta)* are the most prolific while *Bacillariophyta* of the genus *Aulacoseira* (*Aulacoseira islandica* and *Aulacoseira granulata*) dominate with respect to biomass. The southern part of Lake Yandomozero is dominated in terms of population by *Bacillariophyta* (taxa of the genus *Aulacoseira*) and the *Cyanophyta* alga *Anabaena spiroides* while the main contributors to biomass are *Bacillariophyta* of the genus *Aulacoseira*. Main phytoplankton species (Filimonova, 1965) include algae of the genera *Aulacoseira*, *Tabellaria* and *Asterionella.* Also encountered are the *Cyanophyta* algae A*phanizomenon flos-aquae* and *Gloeotrichia echinulata,* the *Chlorophyta* taxa *Pediastrum duplex* and *Cosmarium moniliferum*, along with taxa of the genera *Micrasterias* and *Euastrum*. With the exception of Lake Yandomozero all lakes contain small quantities of phytoplankton.

The smallest numbers of phytoplankton are reported for the littoral zones of lakes Putkozero and Vandozero (population densities of 44 and 331 thousand cells/l, respectively, and biomass 0.18 and 0.51 g/m^3, respectively) and for the pelagic zone of Lake Putkozero (population density of 295 thousand cells/l and biomass 0.30 g/m^3). Phytoplankton is observed to grow more vigorously in the littoral zones of lakes Kosmozero and Yandomozero and in the pelagic zones of all other lakes in Zaonezhye. At these locations population densities of algae are in excess of 1 million cells/l (1018, 1743, 3653 and 6738 thousand cells/l in lakes Vandozero, Kosmozero, Padmozero and Yandomozero, respectively). The biomasses of algae are 1.2 g/m^3 in Lake Vandozero, 1.5 g/m^3 in Lake Kosmozero, 3.08 g/m^3 in Lake Padmozero and 5.43 g/m^3 in Lake Yandomozero (Table 31).

Table 31

Number of taxa, prolificacy and biomass of phytoplankton in the lakes of the Zaonezhye Peninsula

Lake	Number of taxa	Prolificacy (thousand cells/l)	Biomass (g/m^3)
Vandozero	46	1018	1.48
Putkozero	19	295	0.30
Kosmozero	22	1743	1.25
Yandomozero	35	6738	5.43
Padmozero	72	3653	3.08

Analysis of the ecological and geographic pattern of lake phytoplankton has shown that most taxa are widespread in land-locked water bodies. Biogeographically speaking, algal flora is dominated by ubiquitous species (84%) while northern-alpine (9%) and boreal (7%) species are far less common. With respect to response to water salinity most taxa are classified as oligohalobous, 89% of them being indifferent species, and halophobes and halophiles less populous. In terms of pH response, indifferent algae make up 57%, alkaliphilic species 24 % and acidophilic algae 19%. Taxa indicative of saprobic lakes account 66% of all algae. Most of these (94%) are oligo-, oligo-b- and b-mesosaprobes.

Conclusion. The comparative study of the species composition, population density and biomass of phytoplankton in the lakes of national parks unaffected by human activities, i.e. which retain their natural condition, has shown *Bacillariophyta*, *Chlorophyta* and *Chrysophyta* algae to be the dominant groups. These groups of alga were in taxonomic terms the most widely represented. Thus, the following have been identified in the phytoplankton of lakes located in the national parks: *Bacillariophyta* algae (*Aulacoseira*, *Asterionella*, *Tabellaria, Rhizosolenia, Nitzschia*, *Eunotia*, *Fragilaria, Synedra*), *Chlorophyta* algae (chlorococcal *Oocystis, Crucigenia, Monoraphidium, Scenedesmus, Sphaerocystis*, and desmidia *Closterium, Cosmarium, Staurastrum*), various *Chrysophyta* algae (usually *Dinobryon, Mallomonas,* along with nanoplanctonic taxa of the genera *Chrysococcus, Stenokalyx, Kephiryon, Pseudokephiryon*), and *Cyanophyta* algae (*Microcystis, Planktotrix, Aphanizomenon*). The observation of these algae in a variety of northern lakes confirms the recordings of other authors (Chekryzheva, 1990; Getsen, 1985; Ìironova & Pokrovskaya, 1967; Nikulina, 1977; Trifonova & Petrova, 1994). These researchers reported the presence of *Euglenophyta*, *Cryptophyta* and *Dinophyta* algae in all northern lakes.

Most taxa of phytoplankton occurring in the lakes of the national parks are planktonic forms and are widespread in land-locked water bodies. Benthos and periphyton mostly consist of diatoms. On the basis of their observed response to water salinity most taxa present are oligohalobous. Of these the majority are indifferent species while halophobous and halophilic species are far less common. With the exception of diatoms we have only scant information concerning the pH response of algal species. Indifferent and acidophilic algae form the largest group. Algae which indicate the saprobic level of lakes make up over 50% of all algal taxa. Most of these (90 %) are oligo-b-mesosaprobes and b-mesosaprobes. Oligosaprobes indicate a good level of water purity and found in large quantities. However, algae restricted to totally unpolluted waters, i.e. xenosaprobes and oligo-xenosaprobes (*Bacillariophyta* species *Eunotia lunaris, Meridion circulare* and *Cymbella helvetica*) are scarce. Conversely, algae indicative of heavy contamination, i.e. a- and a-b-mesosaprobes (*Bacillariophyta* species *Navicula cryptocephala* and *Nitzschia acicularis*) are also scarce.

Appendix

Species composition of lake phytoplankton. Lake number is given in the map

Taxa	Occurrence in lakes
Cyanophyta	
Anabaena lemmermanii O.Richt.	4, 7, 8, 11, 12, 23
A. scheremetievi Richt.	3, 7, 8, 11, 12,
A. spiroides Kleb.	20, 22, 23
Anabaena sp.	2, 5, 6, 10, 14, 17, 20
Aphanizomenon flos-aquae L. Ralfs. f. *flos-aquae*	7, 10, 19
Aphanothece clathrata W. Et G. S. West	7, 8, 10, 22–24
Chroococcus sp.	7, 10
Coenocloris sp.	10
Coelosphaerium kuetzingianum (Naeg.)	23
Gloeocapsa minuta Kuetz. Holler.	7, 12
G. limnetica (Lemm) Hollerb.	14
G. turgida (Kuetz.) Hollerb.	7
Gloeocapsa spp.	1, 7, 9
Gloeothece sp.	7
Gomphosphaeria lacustris Chod.	22, 23
Lyngbya limnetica Lemm.	12
Merismopedia tenuissima Lemm.	5, 7–14, 16, 17, 19
Microcystis aeruginosa Kuetz.	22, 23
Oscillatoria sp.	17, 20
Planktotrix agardhii Gom. f. *agardhii*	20, 21, 23
Pseudoanabaena limnetica Lemm.	7
Snowella sp.	8
Synechocystis minuscula Woronich.	12
Woronichinia naegeliana (Ung.) Elenk.	22, 23
Chrysophyta	
Chrysococcus rufescens Klebs. var. *rufescens*	1–11, 13–17, 20, 24
C. cordiformis Naum.	1, 2, 4–11, 15–7, 19, 20–24
C. punctiformis Pasch.	7-10, 13
Chrysochromulina parvula Lackey	4, 6, 14, 17,
Chrysopyxis iwanoffii Laut.	12
Dinobryon acuminatum Ruttn.	12
D. bavaricum Imh. var.*bavaricum*	1–8, 10, 12, 14, 16, 18, 20, 22, 24
D. borgei Lemm.	8, 12, 24
D. cylindricum Imh. var.*cylindricum*	1, 24
D. cylindricum var.*palustre* Lemm.	1
D. divergens Imh. var.*divergens*	3–7, 10, 14, 16, 19, 20, 24
D. pediforme (Lemm.) Stein.	24
D. suecicum Lemm.	8, 9, 18
D. sertularia Ehr. var. *sertularia*	10, 22
Kephiryon boreale Skuja	8, 10, 11, 13
K. cupuliforme Conrad	1, 14, 16
K. spirale (Lack.) Corn.	7, 10
K. ovum Pash.	7, 8, 13, 17
Mallomonas acaroides Perty	3
M. acrocomos Ruttn. in Pasch.	11
M. allorgei (Defl.)	11
M. caudata Ivan. et. Krieg.	3, 7, 8, 10, 11
M. denticulata Matv.	7
M. punctifera Korsch.	8
Mallomonas spp.	3-9, 12, 16, 17, 19,
Paraphyzomonas vestila (Stokes) De Saedeleer	2
Pedinella hexacostata Wyss.	12
Pseudokephyrion entzii (Schill.) Schmid.	2, 4–6, 13, 17–19,
Pseudokephyrion latum (Schill.) Schmid.	7, 8
Pseudopedinella elastica Skuja	15, 16, 18, 19
Spiniferomonas spp.	9
Stenokalyx densata Schmid	7, 8, 10, 12, 13, 22, 24
Synura spp.	12
Uroglena spp.	7
Uroglenopsis europaea Pasch.	12
Bacillariophyta	
Acanthoceros zachariasii (Brun) Simons.	7, 10, 11
Achnanthes minutissima Kuetz. var. *minutissima*	1, 5, 8

Taxa	**Occurrence in lakes**
Amphora ovalis Kuetz. var. *ovalis*	20, 23, 24
A. coffeaformis Ag.	20
Asterionella formosa Hass. var. *formosa*	1–3, 5–11, 13, 14, 16–18, 20–24
A. gracillima (Hantzsch.) Heib.	7, 18
Aulacosira ambigua (Grun.) Simons.	2, 4, 8–11, 13
A. subarctica (O.Mull.) Haworth.	1, 4-11, 13-16, 18-24
A. distans (Ehr.) Simons.	3, 5–11, 13, 14, 17–19, 20
A. italica var. tenuissima (Grun) O. Mull.	6–11, 13, 20, 21, 23, 24
A. islandica subsp. helvetica O. Mull.	2, 4, 6, 7, 9, 11, 20–24
A. alpigena (Grun.) Krammer	7–9, 12, 20–22
A. granulata (Ehr.) Ralfs var. *granulata*	22–24
Melosira varians Ag.	7, 9
M. lirata Kutz.	8
M. undulata (Ehr.) Kuetz.	10, 24
Cocconeis placentula Ehr. var. *placentula*	21
Cocconeis spp.	4, 9, 10, 24
Cyclotella comta (Ehr.) Kuetz.	10, 20–24
C. bodanica Eulenst. var. *bodanica*	10, 20–24
C. kuetzingiana Thw. var. *kuetzingiana*	7
C. stelligera Cl. et Grun.	7, 24
Cyclotella spp.	2, 5, 7, 9, 14, 16, 20
Cymbella ventricosa Kuetz.	1, 20, 24
C. helvetica Kuetz.	24
C. hebridica (Greg.) Grun.	24
C. cymbiformis (Ag.) Kuetz. var. *cymbiformis*	9, 24
C. prostrata (Berk.)	22
C. turgida (Greg.) Grun	24
Cymbella sp.	8, 9, 10
Cymatopleura solea var. subconstricta O. Mull.	22
Diatoma elongatum (Lyngb.) Ag. var. *elongatum*	8
Didymosphaenia geminata (Lyngb.) M. Schmidt.	7
Diploneis parma Cl.	20, 22, 24
Epitemia argus Kuetz.	21, 23
E. zebra var. porcellum (Kuetz.) Grun.	3, 21
E. zebra (Ehr.) Kuetz. var. *zebra*	20–23
Eunotia arcus Ehr. var. *arcus*	14
E. bidentula W.Sm.	8
E. fallax A. Cl.	17
E. formica Ehr.	7
E. lunaris (Ehr.) Grun var. *lunaris*	1, 7, 10, 11,
E. pectinalis var. ventralis (Ehr.) Grun.	1, 7–11, 13, 18–20
E. robusta var. tetraedon (Ehr.) Ralfs.	11, 13
E. valida Hust.	9, 13
Eunotia sp.	6
Fragilaria crotonensis Kitt.	20–24
F. construens (Ehr.) var. *construens*	23, 24
F. capucina Desm. var. *capucina*	7, 18
Fragilaria spp.	7, 10, 11
Frustulia rhomboides (Ehr.) D.T. var. *rhomboides*	3, 6–8, 10, 11, 14, 17, 18,
Gomphonema acuminatum var. coronatum (Ehr.) W. Sm.	1, 3, 6, 8, 10, 20, 23, 24
G. olivaceum (Lyngb.) Kuetz.	6, 21, 22, 24
Gomphonema sp.sp.	10, 11
Gyrosigma acuminatum (Kuetz.) Rabenh. var. *acuminatum*	8, 20, 21, 24
Meridion circulare (Grev.) var. *circulare*	10
Navicula lanceolata Kuetz. var. *lanceolata*	7
N. radiosa Kuetz.	20, 22–24
N. cryptocephala Kuetz. var. *cryptocephala*	23, 24
Navicula spp.	2–4, 11, 17, 18
Nitzschia linearis W. Sm. var. *linearis*	5
N. acicularis W. Sm. var. *acicularis*	3, 4, 7, 11, 20–24
N. angustata var. *acuta* Grun.	7
N. hungarica Grun.	7
N. recta Hantzsch.	10
N. vermicularis (Kuetz.) Grun.	24
N. linearis var. tenuis (W. Sm.) Grun.	20, 23
N. sigmoidea (Ehr.) W. Sm.	24

Taxa	Occurrence in lakes
Nitzschia spp.	3, 6–8, 11, 18,
Pinnularia interrupta W. Sm.	23, 24
P. undulata Greg. var. *undulata*	4, 20, 21, 24
Pinnularia spp.	7
Rhizosolenia longiseta Zach.	3, 6, 12, 17, 19, 20, 24
R. eriensis H. L. Sm.	7–9, 13
Rhoicosphaenia curvata (Kuetz.) Grun. var. *curvata*	11
Rhopalodia gibba (Ehr.) O. Mull. var. *gibba*	20, 22
Hantzschia amphioxys f. *capitata* Ehr. (Grun.)	20
Hantzschia sp.	7
Stauroneis anceps Ehr. f. *anceps*	7, 11, 23, 24
Stephanodiscus astreae var. *intermedia* Ehr. Grun.	13, 24
Surirella capronii Breb. var. *capronii*	7
S. biseriata var. *bitrons* Greg. Hust.	20
S. biseriata var. *constricta* Grun.	24
S. robusta Ehr. var. *robusta*	7
Synedra acus Kuetz. var. *acus*	1, 24
S. acus Kuetz. var. *radians* (Kuetz.)	12
S. ulna (Nitzsch.) Ehr. var. *ulna*	1, 3, 7, 20–22
Tabellaria fenestrata (Lyngb.) Kuetz. var. *fenestrata*	1-15, 17, 19, 20-23
T. fenestrata var. *intermedia* Grun.	1, 2, 4, 6–11, 14, 17–19, 23
T. flocculosa (Roth.) Kuetz.	8–10, 12
Tetracyclus lacustris Ralfs.	1, 7, 8, 13, 14
Xanthophyta	
Ophiocytium capitatum Wolle	3, 4
Tribonema affine West.	11
Cryptophyta	
Rhodomonas lacustris Pasch. et Ruttn.	2, 4, 6–8, 10, 11, 13, 14, 16, 17
Croomonas spp.	7
C. acuta Uterm.	12
Cryptomonas marssonii Skuja	12
C. reflexa (Marsson.) Skuja	12
C. rostrata Troitzs. emend. I. Kiss.	12
Cryptomonas spp.	2-7, 10-19, 24
Dinophyta	
Ceratium hirundinella (O. F. M.) Bergh.	12
Glenodinium spp.	3–7, 10, 12, 13, 15, 16, 18, 19
G. quadridens (Stein.) Schiller.	10
Gymnodinium spp.	12, 24
Peridinium goslaviense Woloszynska	1, 3, 4, 13, 15–17
P. cinctum (O.F.M.) Ehr.	2, 6, 12, 14, 18, 22–24
P. inconspicuum Lemm.	5, 12, 13
Peridinium sp.	2, 3, 13–15
Euglenophyta	
Trachelomonas volvocina Ehr. var. *volvocina*	2-4, 6, 7, 9–11, 13–16, 20, 22–24
T. volvocina var. *subglobosa* Lemm.	9
T.hispida (Perty) Stein. Emend.Delf. var. *hispida*	1, 2, 8, 10, 23, 24
T. hispida var. *crenulatocollis* (Mashell.) Lemm.	8
Astasia sp.	20
Euglena acus Ehr. var. *acus*	1, 13, 17, 19
Chlorophyta	
Ankyra juday (G. M. Smith.) Fott.	8
Ankistrodesmus falcatus (Corda) Ralfs	10, 11
A. fusiformis Corda.	7, 10, 24
A. braunii Brunnth.	12
Botryococcus braunii Kuetz.	12
Chlamydomonas spp.	2 - 20
C. monadina Stein var. *monadina*	1, 4, 7, 13-18, 20, 21, 24
Closterium gracile Breb.	7-9
C. kuetzingii Breb.	7
Cosmarium contractum Kirchner	17
C. phaseolus Breb.	20, 24
C. portianum Archer	14
C. meneghinii Breb.	20
Cosmarium obsoletum (Hantzsch.) Heinsch.	4, 16, 18
Cosmarium spp.	10, 11
Crucigenia tetrapedia (Kirchn.) W. et G. S. West	4, 7, 10. 11, 14-16, 18, 24

Taxa	Occurrence in lakes
C. quadrata Morren	3
C. rectangularis (A. Br.) Gay	7
C. fenestrata Schmid. (Schnidl.)	12, 24
Coelastrum sphaericum Naeg	7, 22, 23
Coelospherium minutissimum Lemm	22
Coenochloris pyrenoidosa Korchik.	7
Dictyosphaerium pulchellum Wood. var. *pulchellum*	4, 7, 14, 16
D. ehrenbergianum Naeg.	7
Didymogenes palatina Schmidle.	14, 19, 24
Eudorina elegans Ehr.	7, 8
Elakatotrix gelatinosa Wille	8, 11, 24
E. lacustris Korschik.	2, 5, 10, 12, 14, 18,
Euastrum elegans (Breb.) Kuetz.	9, 18
Golenkinia radiata Chod.	7
Kirchneriella obesa (W. West) Schmidle	3, 4, 14-16
K. contorta (Schmidle) Bohl.	7,
Koliella longiseta (Vischer.)Hind.	7, 10, 11,
Lagerchemia spp.	8
Lambertia ocellata Korchik.	12
Lobomonas sp.	16
Micractinium quadrisetum (Lemm.) G. M.Smith.	17
Monoraphidium contortum (Thur.) Kom.-Legn.	7, 13, 15, 18, 20, 24
M. mirabile (W. et G. S. West) Pankov	7, 10, 13, 20, 21, 23, 24
M. dubowski (Woloszynska) Hindak & Komarkova-Legenerova	7, 11, 18
M. minutum (Naeg.) Komarkova-Legenerova	7
M. komarkovae Nygaard.	13, 24
Quadringula closterioides (Bohl.)	7, 10
Oocystis lacustris Chod.	5, 7, 11, 14, 18, 24
O. elliptica W. West.	8
O. solitaria Wittr. in Wittr. et Nordst.	7, 24
Oocystis spp.	7, 8
Oedogonium sp.	7, 8
Pandorina morum (O. F. Mull.) Bory	4, 6, 7, 16
Pediastrum boryanum (Turp.) Menegh.	19, 22, 24
P. duplex Meyen.	22, 23, 24
P. tetras (Ehr.) Ralfs.	23, 24
Planctococcus sphaerocystiformis Korschik.	1, 5, 7, 8, 10, 11, 14, 17, 18, 20–23
Planktosphaeria gelatinosa G. M. Smith.	6
Rahpidonema longiseta Vischer.	12, 24
Scenedesmus quadricauda (Turp.) Kuetz.	12, 14, 17, 18, 23, 24
S. quadricauda var. *cetosus* Kirchn	24
S. bijugatus (Turp.) Kuetz. Var. *bijugatus*	7, 21, 22, 24
S. disciformis (Chod.) Fott	23
Staurodesmus triangularis (Lagerh.) Teil.	7, 8, 11, 24
S. leptodermus (Lund) Teil. Cl.	24
S. incus var. *ralfsii* (W. West) Teiling	7
Schroederia setigera (Schroed.) Lemm	7 - 9, 15, 24
Sphaerocystis planctonica Korschik.	7, 8
S. schroeteri Chod.	7
Staurastrum paradoxum Meyen. var. *paradoxum*	9, 11, 13, 14, 20
S. gracile Ralfs. var. *gracile*	10
Staurodesmus triangularis Teil var. *triangularis*	7, 8, 11, 24
Tetraedron minimum (A. Braun) Hansgirg	2, 14, 17, 18, 23, 24
T. minimum var. *longispinum* Delf.	1, 12
T. incus (Teil) G. M. Sm. var. *incus*	12
Trochischia aciculifera (Lagerh.)Hansg.	7
Raphidophyceae	
Gonyostomum semen (Ehrenb.) Deis.	4, 6, 13, 16,

Note: Lakes in Kalevala National Park (1. Fig. 54): 1 – Sudnozero, 2 – Verkhneye Ladvo, 3 – Srednyeye Ladvo, 4 – Nizhneye Ladvo, 5 – Marya-Sheleka, 6 – Srednyaya Vazha; lakes in Koitajoki National Park (3. Fig. 54): 7 – Ala-Tolvajärvi, 8- Saarijärvi, 9 – Yla-Tolvajärvi, 10 – Jurikkajärvi, 11 - Sarsajärvi, 12 – Tolvajärvi, 13 – Saynejärvi, 14 – Pieni-Kuohajärvi, 15 – Sochkusjärvi, 16 – Suuri-Kuohajärvi, 17 – Kangasjärvi, 18 – Kylajärvi; lakes in Tuulos National Park (8. Fig. 54): 19 – Tuulos; lakes on Zaonezhye Peninsula (5. Fig. 54): 20 – Vandozero, 21 – Putkozero, 22 – Kosmozero, 23 – Yandomozero, 24 – Padmozero.

To sum up, the phytoplanktonic communities of the lakes studied are taxonomically diverse. Their quantitative development indices estimated with respect to the type of water body (Kitaev, 1984; Trifonova, 1990) indicate differences between the trophic levels of various lake types. Eighteen of the twenty-five lakes studied (Sudnozero(Venehjärvi), Verkhneye, Srednyey Ladvo, Marya-Sheleka, Juurikkajärvi, Saarijärvi, Yla-Tolvajärvi, Sarsajärvi, Ala-Tolvajärvi, Saäynejärvi, Sonkusjärvi, Pieni-Kuohajärvi, Suuri-Kuohajärvi, Kangasjärvi, Kyljärvi, Tuulos and Putkozero) are oligotrophic while the seven remaining lakes (Nizhneye Ladvo, Srednyaya Vazha, Tolvajärvi, Vandozero, Kosmozero, Yandomozero and Padmozero) are mesotrophic. Almost all the lakes in the Kalevala national park, Koitajoki and Tuulos natureal parks are oligotrophic in contrast to the lakes located in the Zaonezhye Peninsula which are mesotrophic.

It should be noted that, with the exception of certain lakes located in the Zaonezye Peninsula (Filimonova, 1965), this has been the first mapping study of algal flora to be undertaken in the lakes of the national parks. Considering the unique biotic pattern of these lakes and their value as points of reference with respect to the natural condition of lakes in general, it is desirable to continue the study of the species diversity of their planktonic algal flora in greater detail.

4.2 Periphyton

Introduction. In most regions of Russia small rivers are usually the least studied water ecosystems even though they play a key role in the establishment of water balance and are used for commercial fishing, water supply and recreational purposes. This is especially true in Karelia where the hydrographic network is structurally dependent on small rivers and the lake-river systems which they form.

Algal flora is the most sensitive constituent of aquatic ecosystems and significantly influences the structure and functioning of all ecosystem components. One advantage of algological studies in the monitoring of aquatic ecosystems is the short life cycle of algae. This enables researchers not only to assess the present state of water bodies through short-term observations but also to predict possible changes. However, in spite of large-scale floristic studies we know very little about many areas. Studies are usually conducted on large water bodies where attention is mainly directed towards to plants of practical or commercial value. Other plants, especially microscopic species requiring special sampling and analytical methods, are neglected.

Considerable success has been achieved in many fields of modern hydrobiology. Nevertheless, the floristic aspects of algology remain important and the algological study of northern water bodies is becoming increasingly relevant. This is because as the hydrological environment deteriorates algae start to play a more important role in ecosystems than do macrophytes.

The aim of our project was the study of periphyton because attached communities are unaffected by accidental, local short-term changes in the hydrologic and hydrochemical system. Instead they reflect the system averaged over time which dominates in the water body in question. The algal cenoses of attached organisms are analysed structurally in order to ascertain how and by what a water body has previously been influenced. Periphyton is a classic example of an ecotonic boundary community the formation of which is affected by benthic and planktonic algal cenoses. Therefore, analysis of the species composition of periphyton enables scientists to structurally assess phytoplankton and microphytobenthos in adjacent zones and thus provide a better understanding of algal flora in water bodies. However, until the 1970s when the study of periphyton began in earnest our knowledge of the algal flora of periphyton in Karelian streams was limited to data obtained by V.S. Poretsky (Poretsky, 1927) and V.K. Chernov (Chernov, 1927à, b).

Material and methods. This present paper reports the results of algological studies carried out for the first time during 1997-1999 in twenty rivers located in the various parts of Karelia (Fig. 55). This data was compared with that obtained earlier for rivers in North European Russia between Lake Ladoga and the Barents Sea. (Komulainen, 1978, 1990, 1994, 1995a,b, 1996a,b, 1998, 1999; Genkal, Komulainen, 2000).

Periphyton samples were collected during the summer low-water period (July-August). Depending on the size of the river between five and ten sampling sites were chosen. Throughout the investigation standard sampling techniques were employed. Approximately ten samples were collected at each site. Wherever possible this was done by scraping the surface of rocks, stones and pebbles. In other cases it was performed by squeezing mosses (*Fontinalis* spp.*)* and macroscopic algae or by scraping the surface of stems and leaves of vascular plants (*Equisetum fluviatile* L., *Phragmites australis* (Cav.) Trin. ex Steud., *Myriophyllum* spp.).

The periphytic algae were collected in tubes of equal volume and preserved in formaldehyde. In the laboratory the samples were studied in two steps. Firstly, filamentous algae were analysed using the counting chamber technique at a magnification of 150×. At the same time the ratio of filamentous algae to diatoms was estimated. Secondly, diatoms were purified ready for identification by gently boiling the acid mixture (a 2:1 mixture of concentrated nitric and sulphuric acids, boiling time 2–4 hours). Diatom slides were mounted in Hyrax. Identifications were made at 1000× under oil immersion. Microscopy was used to measure algal cells while biovolume was determined using the table appearing in Kuzmin's treatise (Kuzmin, 1900). Figures describing algal population density and biomass were presented in terms of numbers of cells and fresh weight in mg per cm^2 of substrata. Species with relative population densities of ≥1% of the total algal flora of a river are considered to be dominant.

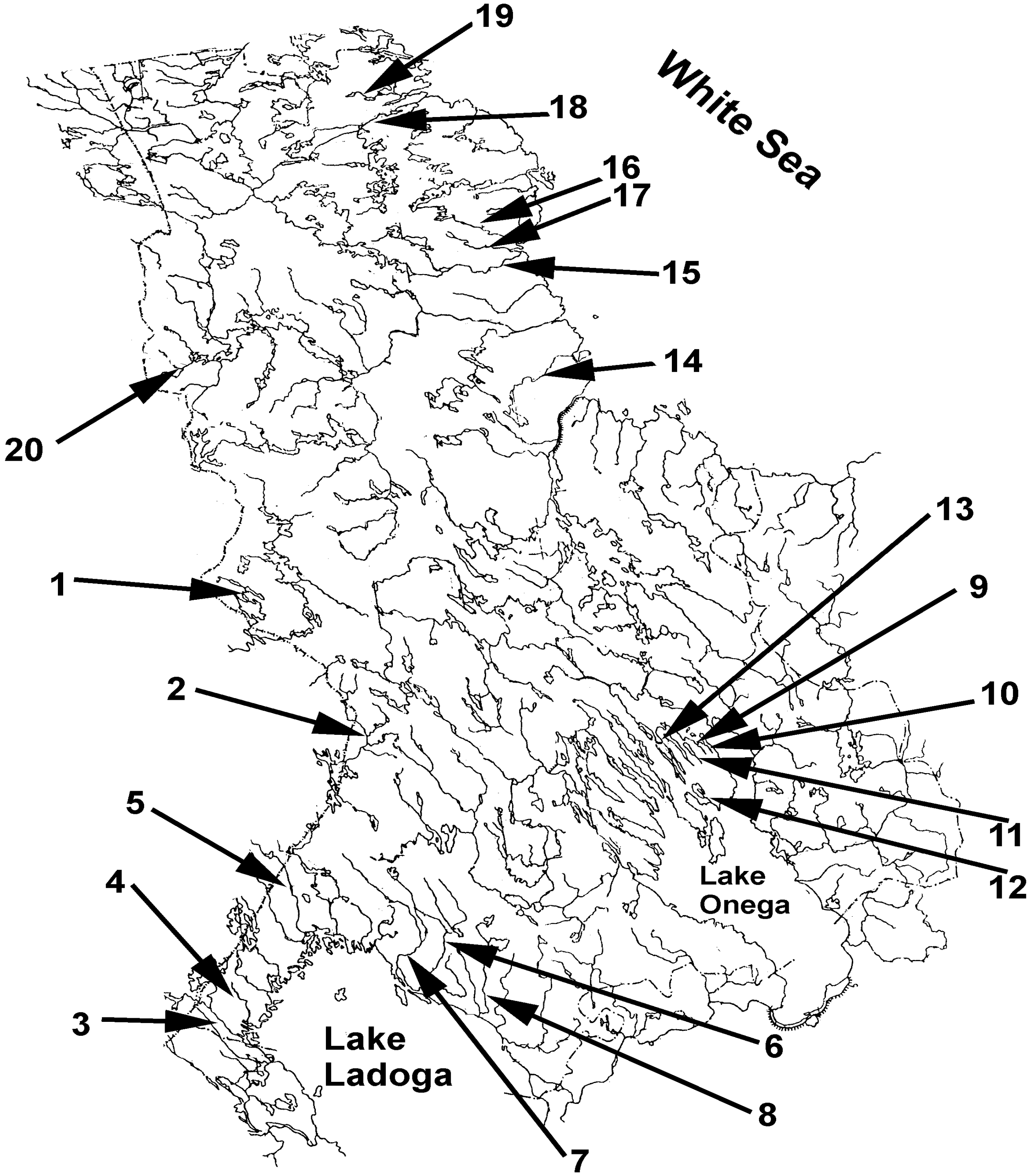

Fig. 55. Location of the rivers studied

Symbols used: 1 – Koroppi, 2 – Koitajoki, 3 – Hiitalanjoki, 4 – Suksunjoki, 5 – Tohmajoki, 6 – Tulemajoki, 7 – Uksunjoki, 8 – Vidlitsa, 9 – Tsarevka, 10 – Kalei, 11 – Padma, 12 – Ugoma, 13 – Yandoma, 14 – Shuya (Belomorian), 15 – Pongoma, 16 – Vonga, 17 – Kuzema, 18 – Keret, 19 – Pulonga (Karelian), 20 – Sudno (Vuokinjoki)

The taxonomy proposed in 'The diatoms of the USSR. Fossil and Recent' (1988, 1992) was adopted for diatoms while that in 'A guide to the identification of freshwater algae of the USSR' (1951–1983) was applied for other groups. Data on the geographic distribution of algae and their responses to salinity and pH was borrowed from various floristic guides.

Results. 175 species of 77 genera, 44 families, 21 orders and 6 divisions were identified in the periphyton of twenty rivers (Appendix 1–2).

Blue-green, green and diatomaceous algae make up 95.4% of the total list (Table 32). Such a division is characteristic of northern water bodies.

Table 32

Position of divisions with respect to the number of taxa in the algal flora of periphyton

DIVISIONS (6)	a	b	c	d	e	f
Cyanophyta	25	14.3	3	18	27.7	2
Chrysophyta	1	0.6	5	0	0.0	5
Bacillariophyta	101	57.7	1	28	43.1	1
Chlorophyta	41	23.4	2	14	21.5	3
Xanthophyta	1	0.6	5	0	0.0	5
Rhodophyta	6	3.4	4	5	7.7	4
Total algal flora	175	100		65	100	

Legend: a – number of species, b – number of species as a percentage of all species, c – position of the order with respect to the number of species, d – number of dominant species in an order, e – number of dominant species in an order as a percentage of all dominant species, f – position of the order with respect to the number of dominant species.

Northern traits typical of the algal flora of periphyton are also apparent at other levels of taxonomic analysis. Comparison of the roles played by various divisions has shown that in all segments of rivers and streams diatoms contribute the greatest towards species diversity and prolificacy in the algal flora of periphyton. This is typical of boreal water bodies.

In northern rivers blue-green algae are generally less diverse than are green algae (Getsen, 1985). The *Cyanophyta*/*Chlorophyta* ratio estimated for periphyton varies from between 0.13 and 2.00 with an average of 0.62. This seems to reflect the specific pattern of attached algal communities. It should be noted that the diversity of green algae rests significantly on presence of representatives of Desmidiaceae which account for 14.3% of all species analysed. At the same time, these do not contribute markedly to the formation of cenoses as they are not prolific. Thus, *Cyanophyta* are even more prolific and diverse in northern Karelian rivers than are *Chlorophyta.*

Another characteristic of the rivers studied is the prolificacy of red algae. Although these are represented by only six species, five of them are considered to be dominant. In particular, Rhodophyta is more prolific in rivers (Koitajoki, Koroppi, Hiitalanjoki, Pongoma) with a high colour index (≥100°).

The most common diatoms are those of the orders Araphales and Raphales. Indeed, these two predominate in algal cenoses (Table 33). Less diverse centric diatoms (orders *Thalassiosirales*, *Pseudopodosirales*, *Melosirales* and *Aulacosirales)* are generally less common, although they occasionally predominate in the periphytonic algal flora of zones located downstream of lakes with relatively rapid flows of supply and discharge water.

The zonal pattern of flora was investigated by calculating the taxon number ratio of the orders *Nostocales* and *Oscillatoriales*. In the rivers studied periphyton is dominated by freshwater algae. Indeed, these are prominent in the

Table 33

Position of orders with respect to the number of specific and intraspecific taxa in periphytonic algal flora

ORDERS (21)	a	b	c	d	e	f
Chroococcales	4	2.3	7	3	4.6	8
Nostocales	10	5.7	4	7	10.8	3
Oscillatoriales	7	4.0	5	5	7.7	4
Araphales	15	8.6	3	8	12.3	2
Raphales	78	44.6	1	16	24.6	1
Ulotrichales	4	2.3	7	4	6.2	5
Zygnematales	28	16.0	2	3	4.6	8
Nemaliales	5	2.9	6	4	6.2	5
Number of species in leading orders	151	86.3		50	76.9	
Total algal flora	175	100		65	100	

Legend: a – number of species, b – number of species as a percentage of all species, c – position of the order with respect to the number of species, d – number of dominant species in an order, e – number of dominant species in an order as a percentage of all dominant species, f – position of the order with respect to the number of dominant species.

cenoses of northern Karelian rivers. The Nostocales/Oscillatoriales ratio for algal flora varies from 0.03–1.00 for rivers in Priladozhye to 0.7–30.0 for those in the White Sea basin.

The northerly location of the catchment areas of the rivers studied is also reflected by the families of algae occurring and the position of these families in the phylogenetic classification of algae (Table 34). The most commonly occurring families are valuable from the diagnostic point of view. In northern regions a relatively small number of families accounts for the majority of species. Thus, in the periphyton of the rivers studied the seven most common families account for almost 60% of all identified algae. The list is topped by families whose species diversity reflects the Holarctic floristic pattern of the Northern Hemisphere. The families *Eunotiaceae*, *Naviculaceae* and *Desmidiaceae* are the most important in this respect.

Comparative assessment shows that the greatest contribution to taxonomic diversity is made by genera dominated by typical attached forms (Table 35). Three major genera, *Eunotia*, *Navicula* and *Gomphonema,* make up 21.7% of the total number of identified species.

Our analysis of the taxonomic composition of the main genera of diatoms also indicates their uneven distribution between river segments. Diatoms of the genera *Fragilaria*, *Ceratoneis*, *Synedra* and *Eunotia* are usually more diverse in the upper stretches of rivers. The typical attached forms of the genera *Cymbella* and *Gomphonema* are distributed evenly throughout the rivers studied. By contrast, freely moving diatoms such as *Navicula* and *Pinnularia* are most diverse and prolific in the lower parts of the rivers.

In northern flora families and genera represented by a single taxon are prevalent (Table 36). This is also true with respect to the floristic proportions (i.e. number of genera and species per family) of algal flora (Table 37). The reduced number of species in families and genera is also due to the low level of surface water mineralisation. Consequently, diatoms display the highest floristic proportions.

Most species identified are epilithic and epiphytic algae. Attached species typical of northern algal flora form the basis of the dominant complex of algal cenoses. Species of the genera *Stigonema*, *Capsosira*, *Tolypothrix*, *Tabellaria*, *Ceratoneis*, *Synedra*, *Achnanthes*, *Gomphonema*, *Zygnema*, *Mougeotia* and *Batrachospermum* are the most commonly encountered.

Table 34

Positions of families with respect to the number of specific and intraspecific taxa in the algal flora of periphyton

FAMILIES	a	b	c	d	e	f
Oscillatoriaceae	7	4.0	7	5	7.8	3
Fragilariaceae	10	5.7	4	6	9.4	2
Eunotiaceae	18	10.3	3	7	10.9	1
Naviculaceae	22	12.6	2	1	1.6	18–31
Cymbellaceae	9	5.1	6	2	3.1	7–17
Gomphonemataceae	10	5.7	4	2	3.1	7–17
Desmidiaceae	25	14.3	1	0	0.0	32–101
Number of species in leading families	101	57.7		23	35.4	
Total algal flora	175	100		65	100	

Legend: a – number of species, b – number of species as a percentage of all species, c – position of the family with respect to the number of species, d – number of dominant species in a family, e – number of dominant species in a family as a percentage of all dominant species, f – position of the family with respect to the number of dominant species.

Table 35

Positions of genera with respect to the number of specific and intraspecific taxa in the algal flora of periphyton

GENERA (77)	a	b	c	d	e	f
Oscillatoria	7	4.0	4	5	7.8	2
Fragilaria	4	2.3	7	3	4.7	3-4
Eunotia	18	10.3	1	7	10.9	1
Navicula	10	5.7	2	0	0.0	13-42
Gomphonema	10	5.7	2	2	3.1	5-12
Nitzschia	4	2.3	7	1	1.6	13-42
Closterium	6	3.4	5	0	0.0	13-42
Cosmarium	5	2.9	6	0	0.0	13-42
Number of species in leading genera	64	36.6		18	27.7	
Total algal flora	175	100		65	100	

Legend: a – number of species, b – number of species as a percentage of all species, c – position of the genus with respect to the number of species, d – number of dominant species in a genus, e – number of dominant species in a genus as a percentage of all dominant species, f – position of the genus with respect to the number of dominant species.

Table 37

Floristic proportions and generic saturation of river algal flora

Divisions (8)	Fm	Gn	Spp	Gn/Fm	Spp/Fm	Spp/Gn
Cyanophyta	12	15	25	1.25	2.08	1.67
Chrysophyta	1	1	1	1.00	1.00	1.00
Bacillariophyta	17	30	101	1.76	5.94	3.37
Chlorophyta	9	24	41	2.67	4.56	1.71
Xanthophyta	1	1	1	1.00	1.00	1.00
Rhodophyta	4	6	6	1.50	1.50	1.00
Total	44	77	175	1.75	3.98	2.27

Legend: *Floristic proportions* – ratio of the number of genera and species in a family; *generic saturation* – number of species in a genus.

Rainfall, melting winter snows and the low rate of evaporation together cause a high level of surface water dilution which is ultimately responsible for the dominance of algal species indifferent to salinity and pH. Halobic values are known for 120 algal taxa. Most of these are oligohalobionts, indifferent algae making up 70.7%, halophytic species 13.3% and halophobes 15.0%. Consequently, algal flora is classified as oligohalobic, as is to be expected in predominantly poorly mineralised water. Mesohalobic algae are represented solely by *Navicula peregrina.*

Indifferent algae also dominated in terms of pH sensitivity (66.5% of taxa) with alkaliphilous and acidophilous species making up 18.8% and 14.7%, respectively. The algal flora of periphyton is dominated by common ubiquitous species (40.2% of all taxa), boreal species making up 44.4% and arctalpine algae accounting for 15.4%.

Discussion. As with any natural phytochoria, the taxonomic diversity of periphyton in the rivers studied is a consequence of the zonal location and history of the region as well the landscape characteristics responsible for the morphometry of the water bodies. Most of the dominant algal species identified are typical of cold, oligotrophic water bodies.

The most important indices describing the algal flora of periphyton all tend to emphasise its boreal character. Genuinely high-latitude elements are less important even in the streams of northern Karelia. Heterogeneous climatic conditions are responsible for the structural pattern of a dominant complex composed of widespread eurythermal species characteristic of the taiga zone, stenothermal rheophils of alpine genesis, and a boreal complex of species typical of paludified land. The combination of northern and southern species is typical of the region (Shirshov, 1933). Southern type algal flora includes diatoms of the genera *Cymbella* and *Gomphonema* and the green alga *Cladophora glomerata*.

As periphyton forms in similar hydrologic environments in all the rivers studied and since also these rivers are located in the different parts of Karelia, we were able to study the effect of climate on the structure of periphyton.

Northern Karelian rivers typically contain prolific populations of red algae of the genera *Batrachospermum, Chantransia* and *Lemanea.* Other common species include the cold-resistant arctalpine forms, *Stigonema mamillosum, Tolypothrix tenuis, Tabellaria flocculosa*, *Ceratoneis arcus, Eunotia pectinalis, E. praerupta, E. fallax v. gracilima, E. sudetica, Frustulia rhomboides, Cymbella affinis, Didymosphenia geminata, Oedogonium* spp. and *Zygnema* spp. In northern Karelian rivers boreal species make up the largest single group together with lesser numbers of arctalpine and hypoarctic species which are usually restricted to submontane locations and the upper parts of rivers in southern Karelia.

The decrease in the species diversity in the Arctic zone is often caused by a poor nutrient supply rather than temperature and is related to the chemical composition of water (pH, Ca). Thus, species requiring nitrogen or phosphorous are the first to drop out of the algal cenoses of periphyton in northern Karelia.

On the basis of the taxonomic composition of periphyton at least two groups formed by northern (A) and southern (B) Karelian rivers may be distinguished (Fig. 56).

The highest degrees of association were observed for the periphyton composition of rivers with high humus concentration: Koitajoki, Koroppi, Pongoma, Keret, Vonga, and Kuzema. Attached communities here were dominated by *Batrachospermum moniliforme*, *Tabellaria flocculosa, Eunotia* spp. and various other species common in acid environments. Periphyton communities in the second group (B) were more variable due to differences in river size, levels of mineralisation and/or degree of human impact. Green filamentous algae (*Spirogyra* spp*, Oedogonium* spp, and *Zygnema* spp.) are the most common and prolific here.

Algal cenoses become more diverse as new taxa are added or where the same species occur in different combinations. In the former case the diversity of periphyton depends on allochthonous planktonic or benthic species while the lake surface-drainage ratio is also of importance. The structure of allochthonous algal flora varies with the number, morphometry and trophic status of lakes (Komulainen, 1999). In the latter case diversity is more dependent on the heterogeneity of algal habitats and substrate surface as well as the microdistribution of flow rate together with differences in landscape responsible for the morphometry of streams and the extent of development of littoral vegetation.

The spatial dynamics of periphyton in rivers are generally in accordance with the river continuum concept although their characteristics tends to vary from segment to segment. The alternation of rapids and reaches, the branching pattern of river systems and the occurrence of lakes with circulating water are responsible for the pulse-like pattern of variations in the taxonomic composition and structure of periphyton. Current is a major factor responsible for the mosaic distribution of groups of periphyton as well as the composition of periphyton. Floristic diversity is also favoured by the asynchronous pattern of succession in the various parts of a river system while algal drift explains the

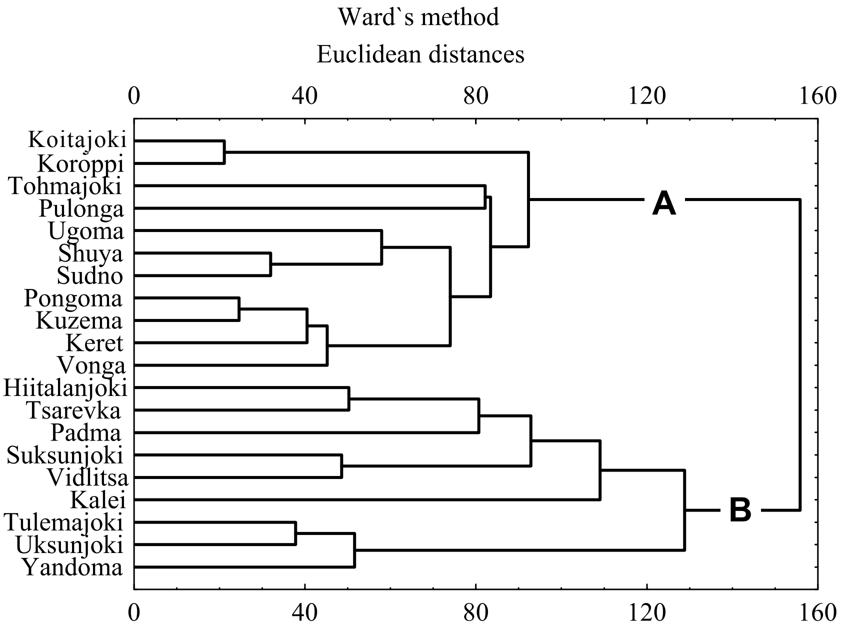

Fig. 56. Dendrogram showing river grouping according to species composition (relatively abundance, N%) of periphyton

simultaneous presence of 'spring', 'summer' and 'autumn' species within algal cenoses. It should be noted that the rate of their formation is mainly determined by illumination. Temperature does not appear to play a significant role. During the optimum development of periphyton the water warms up fairly evenly along the length of a river and temperature variations are not in excess of two degrees centigrade.

The impact of human activities is only observed at the mouths of rivers in Priladozhye (Hiitoalanjoki, Suksunjoki, Tohmajoki, Tulemajoki, Uksunjoki and Vidlitsa). At such locations benthic species become more diverse, the algal structure becomes more simple and the number of dominant species decreases. The β mesosaprobic group of algae (37.0%) is the most widely represented in terms of numbers of species occurring. However, χ, oligo and χ-oligosaprobes also account for 24.2% of those species indicative of high water purity. Species characterising β-α and α saprobic conditions were only very occasionally recorded. Saprobic values estimated (1.0–2.0) indicate that the water of the rivers studied may be classified as oligosaprobic (moderately pure). If the effect of human activities were minimised and the hydrologic system stabilised, the natural structure of algal cenoses would be rapidly restored. It should be noted in this connection that as a result of the ongoing economic and agricultural recession the level of anthropological impact on water bodies has diminished. As the quantity of mineral and biogenic material issuing from catchment areas decreases so the eutrophication of aquatic ecosystems is prevented.

Conclusion. The comparative study of ecologically identical algal cenoses in water bodies located in different geographic and landscape-climatic zones provides information concerning the ecological and geographic distribution pattern of algae. Further data comes from studying parts of water bodies with differing microsystems. The information so gained enables us to demarcate small rivers more correctly.

The rivers discussed are very similar in terms of the composition of mass species to the oligotrophic cold-water rivers of the boreal zone. Periphyton is dominated by species indifferent to salinity and pH. The majority of species occurring are those of diatoms whereas in terms of biomass green, blue-green and red filamentous algae dominate.

The development of mires and the arrangement of dystrophic lakes are not confined to specific landscape or climatic zones. Consequently, their influence on the structure of algal flora is azonal. In spite of being ecologically highly specialised most acidophilic and halophobous species dominating in such water bodies are widespread and ubiquitous. Thus, the catchment areas of the water bodies under comparison must be to some extent paludified.

We have found no considerable variation in the species composition of periphyton to suggest a large-scale restructuring caused by anthropogenic factors. On the basis of the species composition of periphyton and the relative values estimated for individual taxa the water of the rivers studied belongs to the second purest category as described in Sladecek's classification (Sladecek, 1973).

Our observations and analysis of earlier data indicate that the study of Karelian algae has not been evenly pursued throughout the region. It is desirable, therefore, to continue the analysis of the algal flora of periphyton in rivers. Of utmost interest is the segment of eastern Karelia which extends along the border of the Arkhangelsk Oblast, primarily in the southern part of the Pudozh district where the rivers begin to flow down towards the White Sea, Baltic Sea and Caspian Sea. Furthermore, joint Karelian-Finnish hydrobiological studies on certain rivers, e.g. Koitajoki, Lenderka (Lieksanjoki), Luzhma (Tulaijoki), Olanga etc., belonging to the Karelian and Finnish hydrographic networks are needed. The results of such studies would be useful for reference purposes regarding the degree of anthropological impact on water bodies.

Appendix 1

List of algae identified

Taxa	Rivers	Ecology **			
Cyanophyta					
Order Chroococcales					
Family Microcystidaceae					
Microcystis aeruginosa Kütz.*	1, 15, 20	pl	hl	ind	C
Family Gloeocapsaceae					
Gloeocapsa minima (Keissl.) Hollerb.	15, 18	ep	ind	ind	B
Family Gomphosphaeriaceae					
Gomphosphaeria lacustris Ghod. *	6	pl	ind	ind	C
Family Woronichiniaceae					
Woronichinia naegeliana (Ung.) Elenk. *	12,	pl	ind	ind	B
Order Tubiellales					
Family Tubiellaceae					
Johannesbaptistia pellucida (Dickie) Taylor et Drouet	5	pl			
Order Stigonematales					
Family Stigonemataceae					
Stigonema mamillosum (Lyngb.) Ag. *	2, 12, 14–16, 18, 20	ep			
Hapalosiphon fontinalis (Ag.) Born. *	1, 13, 17,	ep			
Family Capsosiraceae					
Capsosira brebissonii Kütz. *	1–3, 7, 14, 15, 17	ep			
Order Nostocales					
Family Nostocaceae					
Sphaeronostoc coeruleum Lyngb.	18	ep			
Stratonostoc commune (Vauch.) Elenk. *	8	ep			
Family Nodulariaceae					
Nodularia spumigena Mert. *	17	ep			
Family Scytonemataceae					
Scytonema crispum (Ag.) Born.	2	ep			
Sc. ocellatum Lyngb. *	17	ep			
Tolypothrix saviczii Kossinsk *	8, 13, 18, 19, 20	ep			
T. tenuis Kütz. *	8, 11, 12, 15, 17, 18	ep			
Family Rivulariaceae					
Calothrix gypsophila (Kütz.) Thur. *	2, 12, 18, 19	ep			
C. kossinskaja var. Poljansk.	9, 18	ep			
C. parietina (Nag.) Thur. *	2, 18, 20	ep			
Order Oscillatoriales					
Family Oscillatoriaceae					
Oscillatoria agardhii Gom. *	3, 5, 18, 19	pl	hl	ind	C
O. amphibia Ag. *	5,	pl	hl	ind	C
O. irrigua (Kütz.) Gom.	2, 4, 5, 19	pl	ind	ind	B
O. limosa Ag.	1,	pl	ind	ind	B
O. nigra Vauch. *	4, 5, 8	pl			
O. sancta (Kütz.) Gom.	3	pl			
O. tenuis Ag. *	1, 3, 7, 19	pl	hl	ind	C
Chrysophyta					
Order Ochromonadales					
Family Dinobryonaceae					
Dinobryon divergens Imhof.	20	pl	ind	ac	B
Bacillariophyta					
Order Thalassiosirales					
Family Stephanodiscaceae Makar.					
Cyclotella bodanica Eulenst	20	pl	ind	ind	Aa
C. kuetzingiana Thw.	13	pl	hl	al	C
Order Pseudopodosirales					
Family Radialiplicataceae					
Ellerbeckia arenaria var. *teres* (Brun.) Crawford	17	b	ind	ind	Aa
Order Melosirales					
Family Melosiraceae					
Melosira undulata (Ehr.) Kütz. *	3–8, 9–11	ep	ind	ind	C
M. varians Ag.	18, 20	pl	hl	al	C
Order Aulacoseirales					
Family Aulacoseiraceae					
Aulacoseira distans (Ehr.) Simonsen. *	1, 2, 15, 16, 18	pl	ind	ind	B

Taxa	Rivers	Ecology			
A. islandica (O. Müll) Simonsen.	20	pl	ind	ind	Aa
A. italica (Kütz.) Simonsen. var. *italica* *	1–3, 5, 6, 8, 9, 11–13, 15–17, 18, 19, 20	pl	ind	ind	C
Order Araphales					
Family Fragilariaceae					
Fragilaria capucina Desm. *	2–4, 6, 15,18	pl	gh	al	C
F. crotonensis Kitt. *	18	pl	hl	al	B
F. pinnata Ehr.	4, 5,	ep	hl	al	C
F. virescens var. *capitata* Østr. *	15, 18, 19	ep	ind	al	Aa
Asterionella formosa Hass. *	5, 15, 16	pl	ind	ind	C
Synedra berolinensis Lemm. *	16	pl	ind	al	C
S. ulna (Nitzsch.) Ehr.*	1, 3–5, 8, 9, 15, 17, 20	ep	ind	al	C
S. vaucheriae Kütz.	4, 6,	ep	ind	ind	B
Ceratoneis arcus (Ehr.) Kütz.	3, 6, 18, 19	ep	ind	al	Aa
***Amphicampa hemicyclus* (Ehr.) Karst.**	17	ep			
Family Diatomaceae					
Meridion circulare Ag.	5, 8, 10				
Family Tabellariaceae					
Tetracyclus emarginatus (Ehr.) Grun.	15	ep	ind	ind	Aa
T. lacustris Ralfs.	2, 5, 7	ep	ind	ind	Aa
Tabellaria fenestrata (Lyngb.) Kütz. *	1, 2, 4–7, 11, 13–17, 20	pl	hb	ac	B
T. flocculosa (Roth.) Kütz. *	1–3, 5–7, 13–20	ep	hb	ac	Aa
Order Raphales					
Family Eunotiaceae					
Eunotia arcus Ehr.	2	ep	ind	al	C
E. bigibba Kütz.	1	ep	ind	ac	Aa
E. clevei Grun.	1	ep	hb	ind	Aa
E. diodon Ehr.	2	ep			
E. fallax A. Cl var. *fallax*	1	ep	hb	ind	C
E. fallax var. *gracillima* Krasske	1, 2, 4, 11, 18	ep	hb	ind	C
E. gracilis (Ehr.) Rabenh. *	3–6				
E. lunaris (Ehr.) Grun. *	1, 2, 11, 23, 15, 17, 18, 19, 20				
E. monodon Ehr.	4, 5,	ep	hb	ac	C
E. paralella Ehr.	1,	ep	ind	ind	Aa
E. pectinalis Kütz. var. *pectinalis* *	1, 2, 4–8, 12, 14, 16, 18, 20	ep	ind	ind	c
E. pectinalis var. *minor* (Kütz.) Rabenh. *	1, 2, 4–7, 18, 20	ep	ind	ac	Aa
E. pectinalis var. *ventralis* (Ehr.) Hust. *	1, 2, 20	ep	ind	ind	C
E. praerupta var. *bidens* (W. SM.) Grun. *	1–4, 15–17, 18, 19	ep	hb	ac	Aa
E. robusta var. *tetraodon* (Ehr.) Ralfs.	1, 2, 18,	ep	ind	ac	Aa
E. sudetica O. Müll *	1, 2, 5–7, 15–17, 20	ep	ind	ind	B
E. tenella Hust.	1	ep	hb	ac	B
E. veneris (Kütz.) O. Müll	1	ep	hb	ind	Aa
Family Achnanthaceae					
Cocconeis placentula Ehr. *	1, 3–5, 8–10, 13	ep	ind	al	B
C. scutellum Ehr.	6				
Eucocconeis flexella Kütz.	2	ep	ind	ind	Aa
Achnanthes clevei Cl	2	ep	ind	ind	C
A. linearis (W. Sm.) Grun.	15, 20	ep	ind	ind	B
A. minutissima Kütz. *	2, 4, 6, 12, 14, 15, 17–19, 20	ep	ind	ind	C
Family Rhoicosphaeniaceae					
Rhoicosphaenia curvata (Kütz.) Grun.	12	ep	hl	al	C
Family Naviculacea					
Navicula cryptocephala Kütz. *var. cryptocephala*	4	b	ind	ind	C
N. exigua (Greg.) O. Müll.	2	b	ind	ind	C
N. gracilis Ehr.	4, 7, 18, 19	b	ind	ind	B
N. lacustris Greg. var. *lacustris*	16	b	ind	ind	B
N. lanceolata (Ag.) Kütz. *lanceolata*	4, 14, 15, 18	b	ind	al	C
N. menisculus Schum.	4, 5, 8	b	hl	al	B
N. peregrina (Ehr.) Kütz.	1, 4, 8	b	mg	al	C
N. placentula Ehr. var. *placentula*	2, 8	b	ind	al	C
N. rhynchocephala Kütz.	11	b	hl	ind	C
N. rotaeana (Rabench.) Grun.	14, 15	b	ind	ind	B
Frustulia rhomboides (Ehr.) D. T. var. *rhomboides**	1–6, 14–20	b	hb	ac	Aa
F. rhomboides var. *Saxonica* (Rabenh.) D. T.	1, 2, 15, 18	b	hb	ac	Aa
Stauroneis anceps Ehr.	1, 10, 18, 20	b	ind	ind	C

Taxa	Rivers	Ecology			
Stauroneis phoenicenteron Ehr.	4, 5, 15	b	ind	ind	B
Pinnularia bogotensis Grun.	15, 16, 18	b			
P. interrupta W. Sm.	4, 18, 19	b	ind	ind	B
P major (Kütz.) Cl	1, 2, 4, 8, 11, 14, 15, 18	b	ind	ind	B
P. mesolepta (Ehr.) W. Sm.	4	b	ind	al	B
P. microstauron (Ehr.) Cl	4	b	ind	ind	B
P. nobilis Ehr.	1, 2, 15, 20	b	ind	ind	B
P. viridis (Nitzsch.) Ehr.	15, 16	b	ind	ind	B
Neidium affine (Ehr.) Cl	2	b	ind	ind	C
Family Cymbellaceae					
Cymbella affinis Kütz. *	1, 2, 4–8, 12, 15, 16, 18, 19	ep	ind	ind	B
C. cesatii (Rabench.) Grun.	3, 19	ep	ind	ac	C
C. cistula (Ehr.) Kirchner.	16, 18, 19	ep	ind	al	B
C. naviculiformis Auersw.	20				
C. sinuata Greg. *	12, 13,	ep	ind	ind	B
C. stuxbergii Cl	8	ep	ind	ind	Aa
C. tumida (Breb.)	3, 8,	ep	ind	ind	B
C. tumidula Grun.	20				
C. ventricosa Kütz.	2, 12, 13, 18, 20	ep	ind	ind	C
Family Gomphonemataceae					
Gomphonema acuminatum (Ehr.)	5, 18, 20	ep	ind	ac	B
G. accuminatum var. *brebissonii* (Kütz.) *Cl*	2	ep	ind	ind	B
G. accuminatum var. *coronatum* (Ehr.) W. Sm.	5, 12, 15, 17, 18, 19	ep	ind	ind	B
G. angustatum (Kütz.) Rabenh	20	ep			B
G. constrictum Ehr. *	1, 3, 4–6, 9, 14, 15, 18, 20	ep	ind	ind	B
G. gracile Ehr. *	5, 20	ep	ind	ind	Aa
G. lanceolatum Ehr.	2	ep	ind	ind	B
G. longiceps Ehr.	2, 4, 5, 10, 18, 19	ep	ind	ind	B
G. olivaceum (Lyngb.) Kütz.	4	ep	ind	ind	B
G. parvulum (Kütz.) Grun. *	1–5, 8, 10–12, 15, 17, 18–20	ep	ind	ind	B
Family Epithemiaceae					
Epithemia sorex Kütz. *	9, 13	ep	hl	al	B
E. turgida (Ehr.) Kütz. *	9, 12, 13, 18	ep	hl	al	B
Family Rhopalodiaceae					
Rhopalodia gibba (Ehr.) O. Müll.	3, 12, 14, 15, 18	ep	ind	ind	C
Family Nitzchiaceae					
Nitzschia capitellata Hust	11	b	hl	ind	B
N. dissipata (Kütz.) Grun.	9–10	b	ind	al	B
N. linearis W. Sm.	2, 4, 9–10	b	ind	ind	B
N. palea (Kütz.) W. Sm. *	2, 16, 18	b	ind	ind	B
Family Surirellaceae					
Surirella biseriata Breb.	3–5	b	ind	ac	C
S. elegans Ehr.	15, 18	b	ind	ind	B
S. tenera Greg.	3	b	ind	ind	B
Cymatopleura elliptica (Breb.) W. Sm.	3	b	ind	al	B
Stenopterobia intermedia Lewis.	2	b	hb	ind	B
Chlorophyta					
Order Chlorococcales					
Family Hydrodictyaceae					
Hydrodictyon reticulatum (L.) Ag.	18	pl			
Pediastrum duplex Meyen.	8	pl			
P. tetras (Ehr.) Ralfs.	8	pl			
Order Ulotrichales					
Family Ulotrichaceae					
Ulothrix tenerrima Kütz. *	1, 5, 10, 20	ep			
Family Microsporaceae					
Microspora amoena (Kütz.) Rabenh.. *	1, 2, 4, 15	ep	ind	ind	B
M. pachyderma (Wille) Lagerh. *	1, 15	pl			
M. tenerrima Kütz. *	4, 5, 17	pl	ind	ind	B
Order Chaetophorales					
Family Chaetophoraceae					
Chaetophora elegans (Roth.) Ag. *	18, 20	ep			
Draparnaldia plumosa (Vauch.) Ag. *	1, 9	ep			
Family Coleochaetoceae					
Coleochaete divergens Pringsh. *	12	ep			

Taxa	Rivers	Ecology			
Order Cladophorales					
Family Cladophoraceae					
Cladophora glomerata (L.) Kütz. *	3, 11	ep	hl		
Order Oedogoniales					
Family Oedogoniaceae					
Bulbochaete sp. *	1, 2, 6, 12, 15, 18	ep			
Oedogonium sp.	1–3, 6, 7, 12, 13, 15–17, 18–20	ep			
Order Zygnematales					
Family Zygnemataceae					
Spirogyra sp. *	2–4, 9–11, 13, 18	ep			
Zygnema sp. *	2, 5, 11, 14–15, 18–20	ep			
Mougeotia sp. *	1, 2, 4–8, 11, 15,17, 19, 20	ep			
Family Desmidiaceae					
Closterium cynthia De Not.	1, 4, 5, 18	pl	hb	C	C
C. dianae Ehr.	2, 4	pl			
C. leibleinii Kütz.	4				
C. moniliferum (Bory.) Ehr.	4, 6–8, 16, 18, 19	pl			
C. parvulum Näg. f. *parvulum*	4, 6	pl	ind	ind	C
C. rostratum Ehr.	1, 18				
Penium spirostriolatum Barker.	6				
Euastrum bidentatum Näg.	1, 4, 6, 17	pl	hb	az	C
E. cuneatum Jenn.	7	pl			
E. pulchellum Breb.	15–18	pl			
Micrasterias radiata Hass.	1, 2	pl	ind	ind	C
Cosmarium abbreviatum Racib.	4, 6				
C. botrytis Menegh.	4, 7, 17–19	pl	ind	ind	C
C. formosulum Hoff.	18, 19				
C. margaritiferum Menegh.	6, 16, 18	pl			
C. pachydermum Lund.	4, 6, 16, 18	pl			
Desmidium swartzii Ag.	16, 19	pl	ind	az	C
Staurastrum floriferum W. et G. S. West.	20				
S. paradoxum Meyen.	2, 17, 18	pl	ind	az	C
Hyalotheca dissiliens (Smith) Breb.	19				
H. mucosa (Mert.) Ehr.	1, 2	pl	hb	az	C
Bambusina brebissonii Kütz.	2	pl			
Spondylosium planum (Wolle) W. et G. S. West.	6				
Xanthidium antilopaeum (Breb.) Kütz.	6				
X. fasciculatum Ehr.	12	pl	ind	ind	C
Xanthophyta					
Order Vaucheriales					
Family Vaucheriaceae					
Vaucheria sp.	4	ep	hl		
Rhodophyta					
Order Compsopogonales					
Family Compsopogonaceae					
Compsopogon chalybeus Kütz. *	12	ep			
Order Nemaliales					
Family Acrochaetiaceae					
Audouinella hermannii (Roth.) Duby*	4	ep			
Chantransia chalybea (Roth.) Fries	1	ep			
Family Batrachospermaceae					
Batrachospermum moniliforme Roth. *	1–4, 15, 17, 18	ep			
Sirodotia suecica Kylin. *	11	ep			
Family Lemaneaceae					
Lemanea fluviatilis Ag. *	1, 15	ep			

Rivers are numbered as follows: 1 – Koitajoki, 2 – Koroppi, 3 – Hiitalanjoki, 4 – Suksunjoki, 5 – Tohmajoki, 6 – Tulemajoki, 7 – Uksunjoki, 8 – Vidlitsa, 9– Tsarevka, 10 – Kalei, 11 – Padma, 12 – Ugoma,13 – Yandoma, 14 – Shuya (White Sea), 15 – Pongoma, 16 – Vonga, 17 – Kuzema, 18 – Keret, 19 – Pulonga (Karelian), 20 – Sudno (Vuokinjoki);

* dominant species (N%≥1.0%).

** The symbols used in the tables presented here are: pl – planktonic, b – benthic, ep – Euperiphytonic, ind – indifferent, hl – halophile, hb – halophobe, mh – mesohalobe, al – alkaliphile, ac – acidophile, Aa – Arctalpine, B – boreal, U – ubiquitous, Spp – number of species, Gn – number of genera, and Fm – number of families.

Appendix 2

Ecological-geographic spectra for the algal flora of periphyton (number of species, %)

Rivers	b	pl	al	ac	ind	hl	hb	ind	Aa	B	C
Koitajoki	12.0	26.0	5.4	35.1	59.5	5.4	37.8	56.8	21.6	29.7	48.7
Koroppi	18.9	20.8	10.3	25.6	64.1	0.0	30.8	69.2	18.0	35.9	46.2
Hiitolanjoki	14.8	14.8	28.6	23.8	47.6	19.1	19.1	61.9	19.1	38.1	42.9
Suksunjoki	26.5	24.5	21.6	24.3	54.1	10.8	24.3	64.9	7.5	50.0	42.5
Tohmajoki	15.2	21.2	11.1	25.9	63.0	14.8	18.5	66.7	14.8	51.9	33.3
Tulemajoki	6.9	37.9	9.5	28.6	61.9	0.0	23.8	76.2	19.1	23.8	57.1
Uksunjoki	21.7	34.8	17.7	23.5	58.8	17.7	11.8	70.6	17.7	47.1	35.3
Vidlitsa	16.7	33.3	26.7	6.7	66.7	6.7	13.3	80.0	6.7	40.0	53.3
Tsarevka	16.7	25.0	60.0	0.0	40.0	30.0	0.0	70.0	0.0	70.0	30.0
Kalei	20.0	10.0	25.0	12.5	62.5	0.0	12.5	87.5	0.0	62.5	37.5
Padma	18.8	18.8	9.1	18.2	72.7	25.0	25.0	50.0	0.0	45.5	54.6
Ugoma	4.4	13.0	14.3	0.0	85.7	20.0	0.0	80.0	0.0	46.2	53.9
Yandoma	0.0	28.6	41.7	25.0	33.3	33.3	16.7	50.0	7.7	46.2	46.2
Shuya(White Sea)	31.3	6.3	7.7	46.2	46.2	0.0	38.5	61.5	15.4	61.5	23.1
Pongoma	22.7	20.5	13.3	13.3	73.3	0.0	23.3	76.7	13.3	56.7	30.0
Vonga	22.7	45.5	14.3	35.7	50.0	0.0	28.6	71.4	14.3	42.9	42.9
Kuzema	10.3	24.1	5.0	40.0	55.0	0.0	35.0	65.0	15.0	40.0	45.0
Keret	20.4	22.2	12.1	30.3	57.6	3.0	27.3	69.7	15.2	42.4	42.4
Pulonga (Karelian)	9.7	29.0	12.5	37.5	50.0	8.3	20.8	70.8	11.5	42.3	46.2
Sudno (Vuokinjoki)	8.6	15.0	11.1	29.6	59.3	7.4	14.8`	77.8	22.2	37.0	40.7
Total algal flora	**18.3**	**30.3**	**18.8**	**14.7**	**66.5**	**13.3**	**15.0**	**71.7**	**15.4**	**44.4**	**40.2**

4.3. Zooplankton

Introduction. The fauna of numerous Karelian lakes and streams has been studied since the 1950s (Gerd, 1946). The latest list of zooplankton species consists of over 600 taxa, including 441 rotifers (*Rotatoria*) and 211 crustaceans *(Calanoida, Cyclopoida, Harpacticoida, Cladocera, Ostracoda)* (Kulikova, 2001). According to S.V. Gerd (1956) Karelia is part of the Karelian-Kola limnological province which has the state border with Finland as its western boundary. The nature, lakes and rivers of most of Finland are very similar to those of Russian Karelia. Comparison of the species composition of Karelian and Finnish fauna have led scientists to conclude that the classes *Crustacea* and *Rotatoria* have much in common (Eriksen, 1969; Hakkari, 1978). The general ecological structure of zooplankton in the two regions is also similar ('Fennoscandian complex') because Finnish and Karelian lakes have similar hydrological and hydrochemical systems, are geographically close to each other and are directly connected by streams.

The aim of our project was to study the species composition of zooplankton in lakes and streams slightly affected by commercial activities. The study made use of existing field evidence, archives and literature. The investigations were carried out on seventy-two water bodies, most of which had not previously been studied. The study area covered the existed protected territories: Kostomuksha Strict Nature Reserve, Paanajärvi and Vodlozero National Parks, some nature reserves on the White Sea coast, and the four proposed National Parks: Kalevala National Park, Tuulos, Koitajoki and Ladoga Skerries NP (Fig. 54, Section «Algal flora of lakes»). A second aim of the study was to assess the quantitative characteristics of biocenoses. The assessment of the constitution of present-day fauna and of how it has changed is important for the preservation of biodiversity in the region.

Methods. Zooplankton was sampled fractionally in large and medium-sized water bodies using a Juday quantitative net (diameter 18 and 25 cm, 0.099 mm mesh sieve). Samples were taken at various depths, i.e. 2–0, 5–2, 10–5, 25–10, 50–25, 75–50, 100–75 metres). The number of Rotifers was calculated from the deposit following plankton sedimentation (Timakova et al., 1998). Shallow lakes with depths of 3–4 metres were treated as having just one layer and therefore samples were collected from the bottom to the surface. River samples were taken by filtering 100 litres of water through an Apstein quantitative net (0.064 mm mesh sieve). Samples were fixed with formaldehyde diluted to 4.0%. Biomasses of organisms were calculated as wet weight according to the formula presented by Balushkina and Vinberg (1979). The hydrological characteristics of water bodies is presented in Section 1.4 and in other publications (Biodiversity inventories…, 1988, 1989, 2000). In all about 800 samples were taken. The supplement contains a list of species the nomenclature of which accords with the present extent of our knowledge (Freshwater invertebrate guide of Russia and adjacent territories. Vol. 2. Crustacea, 1995). We also indicate synonyms (marked « = «) in cases where they have been reported from the area by previous authors. The classification of rotifers follows that of L.À. Kutikova (1970). *Copepods* are classified according to V. M. Rylov (1930, 1948) and *Cladocera* following N. N. Smirnov (1971, 1976). The names and numbers of lakes (lakes with no number are marked 'nn') are given according to the published catalogue 'Surface water resources of the USSR' (1965).

Results. Biogeographic analysis shows that the taxonomic composition of zooplankton in most of the water bodies studied is typical of North Europe. All major species are common to oligotrophic cold water bodies located in the boreal zone. Characteristic of the biolimnological structure of zooplankton is the presence of a cold-water complex. This features *Limnocalanus macrurus* Sars, a glacial sea relict with an upper temperature boundary of about 18° C which occurs in Lake Ladoga, Lake Onega and in four other lakes (Galkovskaja & Sushenya, 1978). Other constituents of the complex are rotifers of the genus *Notholca* which reproduce in the spring-summer, and the *Crustacea – Daphnia longiremis*. A multi-component boreal-limnic complex also occurs and consists of eurythermal, temperate and warm-water species. This complex has a much wider distribution range and displays a growth peak in summer. *Eudiaptomus gracilis, Heterocope appendiculata, Thermocyclops oithonoides, Daphnia cristata, Limnosida frontosa, Sida crystallina, Holopedium gibberum, Bosmina coregoni, Leptodora kindtii, Polyphemus pediculus, Asplanchna priodonta, Kellicottia longispina* Kellicott*, Keratella cochlearis, Bipalpus hudsoni, Conochilus unicornis* and *Filinia longiseta* are amongst the more common species. Many less demanding rotifers are of ubiquitous occurrence as too are the cyclopoids *Mesocyclops leuckarti* and species of the genera *Macrocyclops* and *Paracyclops*. Some Cladocera*,* such as *Bosmina longirostris, Diaphanosoma brachyurum* and *Chydorus sphaericus*, are also ubiquitous. Southern type fauna is poorly represented (*Brachionus*).

The Zooplankton of Karelia is dominated by species of *Cladocera* (40%) and *Rotatoria* (36%) while *Calanoida* make up 4%. *Cyclopoida* (20%) representatives are mostly Northern Hemisphere species (genera *Cyclops* and *Acanthocyclops*) as well as ubiquitous species which often inhabit the weedy littoral zones of water bodies (*Macrocyclops, Paracyclops*). *Daphnia cristata* is the most prolific representative of the *Cladocera* component. Examples of prolific *Copepoda* species are *Eudiaptomus gracilis* which grows all the year round, and the small *Cyclopoida Thermocyclops oithonoides.* As the catchment areas of some water bodies are highly paludified many of their inhabitants adapt themselves to the levels of humus substances in water and can survive considerable variations in pH.

Copepoda dominate in terms of biomass (40–70%) during the spring and autumn while *Cladocera* (40–90%) take over in the summer. Most lakes yield low biomass and population density values in accordance with the oligotrophic type (Kitaev, 1984). However, those located in the southern and southeastern parts of the region, i.e. in Zaonezhye and especially the Vodlozero National Park, contain more varied complexes and higher levels of biological productivity.

Analysis of the environmental and geographic characteristics of the study region has led the authors to conclude that the zooplankton of each water body exhibits its own qualitative and quantitative characteristics with species diversity varying greatly. Planktonic fauna is generally made up of the species already referred to, the relative population densities of which vary markedly from one water body to another.

Paanajärvi National Park: Lake Paanajärvi (73). The great depth, cold water and poorly developed littoral zone of this lake all tend to reduce the productivity of biocenoses. The biomass of zooplankton, over half of which is concentrated in the 0–20 m layer, is not greater than 0.18 g/m^3 in August while the population density is just 5 600 individuals per m^3. The complex consists of thirty-nine species: *Calanoida* 3, *Cyclopoida* 12, *Cladocera* 15 and *Rotatoria* 9 (see Appendix). The northern species *Eudiaptomus gracilis, Eurytemora lacustris, Daphnia cristata, Bosmina coregoni* and *Kellicottia longispina* prevail. Plankton is qualitatively homogeneous throughout the entire lake except for narrow zones formed by macrophytes at river mouths where it also contains phytophilous species (*Sida, Alona* and *Polyphemus*) (Vlasova, 1989).

Tuulos Proposed National Park: Lake Tuulos (1096). The zooplankton of Lake Tuulos in September consists of twenty-one species. Population densities in the pelagic zone are low (1000 inds./m^3) as too is biomass (0.02 g/m^3). Values for the littoral zone are slightly higher (1300 inds./m^3 and 0.06 g/m^3, respectively) The taxonomic composition of the flora is typical of oligotrophic lakes located in the boreal zone (see Appendix). Plankton is dominated by copepods which account 70% of prolificacy and biomass. *Eudiaptomus gracilis, Themocyclops oithonoides* and *Kellicottia longispina* are commonplace. Cladocera (*Bosmina, Ilyocryptus sordidus* etc.) prevail in the littoral zone.

Kalevala Proposed National Park: Lakes Verkhneye (416), Sredneye (417), Nizhneye Ladvo (418), Maria-Sheleka (411), Srednyaya Vazha (nn) and Sudno (410). The zooplankton of these water bodies is made up of northern species. The number of species occurring ranges from seventeen in Lake S. Vazha and N. Ladvo to thirty-two in Lake Sudno (see Appendix). In the pelagic zone of Lake Sudno *Copepoda* dominate in terms of both population sizes (60%) and biomass (70%) during the period from June until August. We also found here a small number of exemplars of the crustacean *Limnocalanus macrurus*. In the pelagic zones of lakes Verkhneye and Nizhneye Ladvo, *Bostina longirostris* together with other *Cladocera* species make up over half of plankton. In lakes Srednyaya Vazha and Maria-Sheleka species of the genus *Bosmina* are found along with *Daphnia cristata*. Complexes are more diverse in the littoral zone where aforementioned inhabitants of pelagic zones occur together with phytophilous and lake bottom species such as *Alonopsis elongata*, *Ophryoxus gracilis* and *Alonella nana*. The lowest population and biomass values (2500 inds./m^3 and 0.1 g/m^3) were reported from Lake Sudno and the highest (76 500 inds./m^3 and 1.75 g/m^3) from Lake Srednyaya Vazha (Table 38).

Table 38

Quantitative characteristics of zooplankton in the lakes of Kalevala National Park

Water body	Date	Number of species	Number, 10^3 ind. m^3	Biomass, g/m^3
Verkhneye Ladvo	29.08.1997	22	22.7	0.28
Sredneye Ladvo	30.08.1997	25	16.4	0.36
Nizhneye Ladvo	30.08.1997	17	38.4	0.75
Maria-Sheleka	02.09.1997	28	13.7	0.45
Srednyaya Vazha	01.08.1997	17	76.5	1.75
Sudno	20.06.1997	32	2.5	0.10

Koitajoki Proposed National Park: Lakes of the Koitajoki River system: Ala-Tolvajärvi (1164), Kangasjärvi (nn), Kylajärvi (1151), Pieni-Kuohajärvi (nn), Saarijärvi (1156), Sarsajärvi (1167), Suuri-Kuohajärvi (1166), Saynejärvi (nn), Tolvajärvi (1171), Yla-Tolvajärvi (1168) and Juurikkajärvi (1170)**.** Planktonic fauna in September consist of forty-six taxa: *Copepoda* 13, *Cladocera* 24 and *Rotatoria* 9. Numbers of taxa found varied from twelve in Lake Tolvajärvi to thirty in Lake Ala-Tolvajärvi (see Appendix). All the lakes are similar in terms of the species composition and prolificacy of zooplankton. Most species found are typical to the region, and occur in varying quantities in all lakes. However, there are some differences in the relative proportions of the major groups. Thus, for example, most lakes are dominated by *Daphnia cristata*, a common all-year-round species of *Cladocera*, with *Holopedium gibberum* also occurring. However, in lakes Kangasjärvi and Yla-Tolvojärvi Copepoda *(Eudiaptomus gracilis, Thermocyclops oithonoides*) make up over 70% of total biomass. At the same time, the proportion of Calanoida in lakes Kylajärvi and Saynejärvi is low (1–2%). In the littoral zone complexes are made up of both pelagic (*Thermocyclops oithonoides, Mesocyclops leuckarti, Daphnia cristata*) and littoral phytophilous (*Ophryoxus gracilis, Chydorus sphaericus, Eurycercus lamellatus*) species. Quantitative values during the autumn are small (average values of 7300 inds./m^3 and 0.3 g/m^3), and vary slightly from one lake to the next, with the exception of Lake Saynejärvi where they rise to 64 100 inds./m^3 and 1.5 g/m^3 (Table 39). On the basis on these indices the lakes of the Koitajoki river system are classified as oligotrophic with some indications of mesotrophy.

Table 39

Quantitative characteristics of zooplankton in the lakes of the Koitajoki River system

Water body	Date	Number of species	Number, 10^3 inds./m ^{3}	Biomass, g/m ^{3}
Jurikkajärvi	27.09.1995	26	7.1	0.32
Saarijärvi	26.09.1994	29	8.7	0.24
Ylä-Tolvajärvi	30.09.1994	19	6.5	0.20
Sarsajärvi	26.09.1995	24	7.8	0.50
Ala-Tolvajärvi	01.10.1994	30	9.2	0.44
Säynejärvi	29.09.1997	16	64.1	1.53
Soncusjärvi	29.09.1997	13	13.1	1.00
Pieni-Kuohajärvi	25.09.1997	21	6.9	0.30
Suuri-Kuohajärvi	25.09.1997	18	10.4	0.28
Kangasjärvi	20.09.1997	13	9.1	0.30
Kyläjärvi	29.09.1997	16	4.3	0.10

Vodlozero National Park: Lakes Vodlozero (1901), Zadneye (1918), Ik (1921), Kalgachinskoye (1912), Kerazhozero (1911), Kopozero (1920), Luzskoye (1923), Melnichnoye 1(nn) and Melnichnoye 2 (1922), Mogzhozero (1825), Monastyrskoye (1919), Nelmozero (1926), Novgudozero (1927), Nosovskoye (1917), Ukhtozero (1913), Chikshozero (1924), Chukozero (1928); Rivers Ileksa (422), Bolshoi Vanruchei (nn) and Kopruchei (nn). Zooplankton consists of forty-nine taxa: *Copepoda* 11, *Cladocera* 23 and *Rotatoria* 15 (see Appendix). These lakes do not vary considerably in terms of the number of species and are inhabited by organisms associated with mesotrophic and eutrophic water, such as *Thermocyclops crassus, Cyclops kolensis, Ceriodaphnia pulchella, Bosmina coregoni* and *Bosmina longirostris*. *Chydorus* sphaericus accounts for 50% (lakes Monastyrskoye and Nosovskoye) to 70% (lakes Nelmozero and Chikshozero) of overall prolificacy and biomass. *Eudiaptomus graciloides, Mesocyclops leuckarti, Limnosida frontosa, Diaphanosoma brachyurum, Daphnia cristata, Leptodora kindtii, Asplanchna herricki, Keratella cochlearis* and *Kellicottia longispina* are all common species (Vislyanskaya et al., 1995). Population densities vary from 51 500 inds./m^3 in Lake Melnichnoye 1 to over 5 million inds/m^3 in Lake Chikshozero while biomass ranges from 0.4 to 27 g/m^3 between the same two lakes. It should be noted that most water bodies in the Ileksa river basin enjoy a high nutrient supply. The nutrient content of lakes varies from low (Melnichnoye) to high (Nosovskoye) and very high (Chikshozero). As these lakes are not affected by human activities their eutrophication is considered to be of natural occurrence.

Kostomuksha Strict Nature Reserve: Lakes Kamennoye (542), Kalivo (543), Munankilampi (556), Mustakivilampi (nn) and Sarkijärvi (nn); Lambas Devichya (nn, on Devichy Island in Lake Kamennoye) and Shchuchya (nn). There are forty-three taxa of zooplankton in Lake Kamennoye, i.e. *Calanoida* 4, *Cyclopoida* 4, *Cladocera* 22 and *Rotatoria* 13 (see Supplement). Kamennoye is an oligotrophic lake with relatively meagre planktonic complexes. The average biomass of zooplankton in July was 0.24 g/m^3 and an average abundance 14 000 inds./m^3 (Gordeyeva, 1986). Low plankton populations are characteristic of the open and littoral surf zones of the lake. In shallow-water bays littoral and phytophilous species add to the faunistic diversity and quantitative values are relatively high (up to 86 000 inds./m^3 and 4.6g/m^3). The distribution of zooplankton is affected by the prevailing southwesterly and southerly winds which cause plankton organisms to concentrate in the northern and northeastern parts of the lake. Consequently, littoral species (*Diaphanosoma*, *Ceriodaphnia*, *Polyphemus*) are joined by pelagic plankton such as *Eudiaptomus gracilis, Eurytemjra lacustris, Limnosida frontosa, Daphnia cristata, Bubosmina coregoni* and *Leptodora kindtii*. A study in October of small, mainly mesopolyhumous lakes, e.g. Munankilampi and Sarkijärvi, revealed 9–13 plankton species dominated by *Daphnia* and *Holopedium.* Quantitative values were low with population densities of 3500 inds./m^3 and biomass 0.3 g/m^3). The zooplankton of lakes Kalivo and Mustakivilampi proves to be even poorer with just five species, 500–1400 inds./m^3 and 0.04g/m^3. *Eudiaptomus graciloides* dominates (70%) in Lake Mustakivilampi. The summer (July) plankton of Devichya Lamba consists of thirteen species. One of the particularly prolific and euryionic species typical of this type of lake (pH 5.3) is *Bosmina obtusirostris* (over 80 000 inds.m^3). *Holopedium* and *Diaphanosoma brachyurum* are also present in large numbers with *Eudiaptomus graciloides* and *Kellicottia longispina* populations increasing in the autumn. Thus, the average number of hydrobionts is over 100 000 inds./m^3 with biomass rising in some cases to 10.8 g/m^3 (in September, 7100 inds./m^3 and 0.2 g/m^3). During the winter season planktonic fauna consist of five species of copepods and rotifers. As during the autumn the most prolific rotifer is *Kellicottia longispina* (ca. 60%) and the most common copepod *Eudiaptomus graciloides* (up to 90% of biomass). Population densities of plankton organisms are as high as 27 100 inds./m^3 with biomass at 0.17 g/m^3. The more diverse zooplankton of Shchuchya Guba consists of twenty-eight species. During the summer *Cladocera* (mostly *Daphnia cristata*) prevails (50–96%), quantitative indices for all forms of *Cladocera* being 22 200 inds./m^3 and 1.25 g/m^3.

Pomorian and Karelian White Sea river estuaries: Vonga (220), Gridina (196), Kalga (201), Kem (269), Keret (161), Kolezhma (721), Kuzema (231), Kyatka (199), Letnyaya (254), Myagreka (484), Nizhma (200), Nyukhcha (733), Pongoma (240), Sig (211), Suma (706) together with lakes Pulozero (892) and Sumozero (901), Unduksa (216), Khlebnaya (215) and Shuya (488) as well as Lake Shuezero (659). These water bodies were studied during the spring-summer period (June, July). Their planktonic fauna consists of sixty-eight taxa: *Copepoda* 16, *Cladocera* 39 and *Rotatoria* 13 (Gordeyeva, 1985; Vlasova, 1985, 1989; Kulikova, 1998; Khazov, 1985, 1986). The number of species occurring in rivers varies from five (Vonga) to thirty-seven (Suma) and forty-five (Kem) while in lakes it ranges from twenty-nine (Pulozero) to sixty (Sumozero and Shuezero) (see Appendix). Lake species dominate the planktonic complexes of the rivers. Large rivers such as the Kem and Suna with high proportions of lake area within their catchment areas contain taxonomically diverse plankton complexes while small rivers with smaller catchment areas and lower proportions of lake surface area contain fewer species.

The best represented group is *Cladocera*. Many of these species are eurytopic organisms which are able to live in the brackish waters of river estuaries. *Eubosmina coregoni* is very common. *Daphnia cristata* is not so ubiquitous and dominates only in the River Unduksa. The most prolific cyclopoids are those of the genus *Cyclops* (found at Gridina, Kalga, Kem, Letnyaya and Shuya) and *Thermocyclops oithonoides* (at Myagreka and Shuya). The most commonly found rotifer is *Kellicottia longispina* (at Letnyaya and Pongoma). In terms of biomass Cladocera account for between 66% (rivers Kalga and Pongoma) and 80–99% in most of the other tributaries studied. Cyclopoida are usually less common and make up 2% (Khlebnaya and Nizhma), 30% (Gridina, Kalga and Myagreka) and 60% (Shuya) of total planktonic biomass. Calanoida (*Eudiaptomus gracilis* and *Heterocope appendiculata*) is relatively scarce, except in the River Kem where *Eudiaptomus* accounts for up to 50% of total population density and biomass. Rotifers contribute significantly to biomass only in the River Unduksa thanks to large populations of *Conochilus hippocrepis.*

The zooplankton of the rivers studied exhibits a typical North European pattern (Kulikova, 1978; Kulikova and Syarki, 1990; Filimonova & Kruglova, 1994) with low population densities and biomasses characteristic. In rivers with rapids, e.g. the River Keret, zooplankton comprises just two or three species (*Bosmina, Chydorus*) with population densities and biomass as low as 100 inds./m^3 and 0.002 g/m^3. Plankton species are more prolific in lakes. Thus, for example, in Lake Sumozero population densities in July vary from 36 000 to 61 200 inds./m^3 and biomass values from 0.50 to 1.7 g/m^3, average values being 33 100 inds./m^3 and 0.58 g/m^3.

Lakes in Zaonezhye: Vangozero (1868), Kosmozero (1870), Padmozero (1859), Putkozero (1862), Chuzhmozero (1871) and Yandomozero (1858). The planktonic fauna of these lakes is quite diverse (see Appendix) with the number of species found in each lake varying from forty in Lake Yandomozero to sixty-one in Lake Putkozero (Filimonova, 1965; Kulikova & Vlasova, 2000). Cladocera prevail (57%). The zooplankton of this area is dominated by a small number of northern species. In lakes Yandomozero and Padmozero *Eudiaptomus graciloides, Chydorus sphaericus* and *Bosmina longirostris* are amongst the most common species. The zooplankton of pelagic zones differs markedly both in terms of dominant species and population densities from that of littoral zones. Species characteristic of the shallow weedy littoral zone include *Sida, Ceriodaphnia, Acroperus, Alonopsis* and *Brachionus longirostris*. *Cladocera* dominates in all lakes and makes up 40–80% of overall biomass. Quantitative indices vary substantially with biomass values highest (1 g/m^3 in the autumn) in the most eutrophic lakes (Kosmozero and Yandomozero). The relict crustacean *Limnocalanus* is encountered in both the deep Lake Putkozero and relatively shallow, nutrient-poor Lake Vangozero.

Kizhi archipelago of the Onega lake (Kizhi Skerries reservation and adjacent lands). The planktonic fauna of this area is locally homogeneous and consists of forty-six taxa. The species composition of the zooplankton found is typical of Lake Onega (Kulikova et al., 1997). Complexes comprise both pelagic and littoral species. The best represented groups are Cladocera and Rotatoria with 41% and 35% of species, respectively. Large sized cold-water *Copepoda* species are scarce. *Eudiaptomus gracilis* and *Thermocyclops oithonoides* occur in large numbers. The *Cladocera* group is dominated by *Daphnia cristata* but during the autumn *Bosmina coregoni* becomes more proli-fic. In organic-rich zones the proportion of rotifers rises to 50% with the species *Polyarthra dolichoptera, Keratella cochlearis* and *Kellicottia longispina* dominating. The Kizhi Skerries is inhabited by a qualitatively varied planktonic fauna and is the most productive area in Lake Onega (Smirnova, 1972; Vislyanskaya et al., 1999). Shallow and relatively warm waters together with well-developed macrophytes shape the typical summer pattern of zooplankton as early as June. During this period the population densities (70 000–140 000 inds./m^3) and biomass values (0.7–2.4 g^3) for the Kizhi Skerries area are the highest in Lake Onega.

Northern skerry zone of Lake Ladoga. A planktonic fauna comprising no less than eighty-eight taxa consists of eurybiont forms dominated by pelagic species. These taxa have also been reported in previous publications (Dengina & Sokolova, 1968; Smirnova, 1982; Telesh, 1996). In the spring and summer (June, August) plankton is dominated in terms of population densities by Rotatoria (60–95%) in the northern part of the lake. Of these the genus *Polyarthra* accounts 20–70% and is accompanied by smaller populations of *Kellicottia, Keratella* and *A. priodonta*. In some zones *Rotatoria* account for 40–65% of total zooplankton biomass. About half of planktonic biomass is made up of *Cladocera* species, mostly *Daphnia cristata* (30–50% of total weight). During the autumn (September) Copepoda begin to play a more important role. Overall population densities and biomass values vary markedly, especially in zones located near industrial centres and affected to unequal degrees by human activities (10 200–588 900 inds./m^3 and 0.19–4.1 g/m^3). Average values are 128 000 inds./m^3 and 1.2 g/m^3. The densest populations (up to 590 000 inds./m^3) and highest degrees of species diversity are chiefly due to the contribution of *Rotatoria* and are observed in the skerries near Pitkaranta. The highest biomass values, deriving mainly from the occurrence of *Cladocera* and the large rotifer *Asplanchna priodonta*, are reported from the Sortavala (2.6 g/m^3) and Laskela (4.1 g/m^3) districts. In the bay close to Sortavala population densities on occasions in June exceed 1 million inds./m^3 and biomass values 7g/m^3. Large numbers (30 000–160 000 inds./m^3) of the species *Brachionus calyciflorus*, indicative of polluted water, are observed there (Kutikova, 1976). The presence of such indicator species suggests that the areas around Sortavala, Laskela and Pitkaranta are the most heavily polluted of those studied so far in Lake Ladoga (Kulikova, Vlasova, 2000).

The inventory and assessment of biodiversity in Karelia has shown that the depth of our knowledge of zooplankton varies from one water body the next. Indeed, most of the water bodies were studied for the first time. Moreover, the investigations conducted in small water bodies were necessarily brief in duration. Thus, the list of species given in the supplement is as yet incomplete and does not describe the full diversity of planktonic fauna in lakes and rivers due to the preliminary character of the investigations. Further studies are needed. We still know little about certain groups of zooplankton, e.g. Rotatoria. The study of numerous small water bodies has helped add more organisms to the known list of Rotatoria species which now includes some 440 taxa (Filimonova & Kutikova, 1975). It is considered most desirable to continue this work in the as yet relatively neglected deep water lakes of Central Karelia (the Selets – Maslozero group of lakes), especially as these water bodies are the least affected by human activities anywhere in Karelia.

Appendix

Species composition of zooplankton in the water bodies studied

CLASS *ROTATORIA*

Order *Ploimida*

Family *Trichocercidae*

***Trichocerca* (s. str.) *elongata* (Gosse, 1886): Vodlozero**

T. (s. str.) *cylindrica* (lmhof, 1891): Vangozero, Vodlozero, Ik, Kalgachinskoye, Kerazhozero, Kopozero, Melnichnoye 2, Mogzhozero, Monastyrskoye, Nelmozero, Novgudozero, Padmozero, Putkozero, Ukhtozero, Chukozero and Yandomozero. Rivers: Ileksa and Kopruchei

T. (s. str.) *longiseta* (Schrank, 1802): Shuezero

Trichocerca sp.: Rivers: Khlebnaya

Family *Gastropodidae*

Gastropus stylifer lmhof, 1891: Shuezero

Family *Synchaetidae*

Synchaeta stylata Wierzejski, 1893: Shuezero

S. lakowitziana Lucks, 1912: Shuezero

S. *oblonga* Ehrenberg, 1831: Chikshozero

S. pectinata Ehrenberg, 1832: Shuezero

S. *kitina* Rousselet, 1902: Kamennoye and Shuezero

Synchaeta sp.: Vangozero, Kalgachinskoye, Kamennoye, Kosmozero, V. Ladvo, N. Ladvo, Melnichnoye 2, Paanajärvi, Padmozero, Putkozero, S. Vazha, S. Ladvo, Saarijärvi, Sudno, Sarkijärvi and Yandomozero. Rivers: Kem and Suma.

Polyarthra luminosa Kutikova, 1962: Shuezero

P. vulgaris Carlin, 1943

= *P. trigla* Ehrenberg: Vangozero, Vodlozero, Putkozero, Kosmozero, Padmozero, Chuzhmozero and Yandomozero

P. dolichoptera Idelson, 1925: Kalgachinskoye, Kamennoye, Melnichnoye 1, Monastyrskoye, Novgudozero, Paanajärvi, Putkozero, Ukhtozero, Chukozero and Shuezero

P. longiremis Carlin, 1943: Shuezero

P. remata Skorikov, 1896: Sumozero and Shuezero

P. major Burckhardt, 1900: Ala-Tolvajärvi, Kamennoye, Kopozero, Saarijärvia, Shuezero and Jurikkajärvi

P. euryptera Wierzejski, 1891: Vangozero, Vodlozero, Ik, Kosmozero, Mogzhozero, Monastyrskoye, Novgudozero, Padmozero, Putkozero, Shuezero and Yandomozero

Polyarthra sp.: Ala-Tolvajärvi, Vodlozero, S. Vazha, S. Ladvo, N. Ladvo, Maria-Sheleka and Sudno. Rivers: B. Vanruchei, Ileksa and Kopruchei

Ploesoma sp.: Kamennoye

Bipalpus hudsoni (lmhof, 1891): Ala-Tolvajärvi, Vangozero, Vodlozero, Ik, Kalgachinskoye, Kangasjärvi, Kamennoye, Kosmozero, Kylajärvi, V. Ladvo, S. Ladvo, N. Ladvo, Maria-Sheleka, Melnichnoye 1 and 2, Monastyrskoye, Novgudozero, Kopozero, Paanajärvi, Padmozero, Pulozero, Putkozero, Saarijärvi, S. Vazha, Sudno, Sumozero, Sarkijärvi, Tuulos, Chuzhmozero, Chukozero, Shuezero , Jurikkajärvi and Yandomozero

Rivers: B. Vanruchei, Vonga, Ileksa, Kem and Pongoma

Family *Dicranophoridae*

Encentrum sp.: Shuezero

Family *Aaplanchnidae*

Aaplanchna herricki Guerne, 1888: Ala-Tolvajärvi, Vangozero, Vodlozero, Ik, Kalgachinskoye, Kosmozero, V. Ladvo, S. Ladvo, N. Ladvo, Luzskoye, S. Vazha, Kopozero, Maria-Sheleka, Mogzhozero, Monastyrskoye, Nelmozero, Novgudozero, Nosovskoye, Padmozero, Putkozero, Sarsajärvi, Tuulos, Ukhtozero, Chukozero, Jula-Tolvajärvi, Jurikkajärvi and Yandomozero. Rivers: B. Vanruchei, Ileksa and Kopruchei

A. priodonta Gosse, 1850: Ala-Tolvajärvi, Vangozero, Vodlozero, Kosmozero, Kylajärvi, V. Ladvo, S. Ladvo, N. Ladvo, Maria-Sheleka, Melnichnoye 2, Monastyrskoye, Novgudozero, Paanajärvi, Padmozero, Putkozero, S. Vazha, Pieni-Kuohajärvi, Pulozero, Saarijärvi, Sarsajärvi, Sudno, Sumozero, Suuri-Kuohajärvi, Tolvajärvi, Chuzhmozero, Shuezero, Shchuchya Lamba, Jula-Tolvajärvi and Yandomozero. Rivers: Kem, Nizhma, Nyukhcha, Suma and Shuya

A. priodonta priodonta Gosse, 1850: Shuezero

A. priodonta helvetica lmhof, 1884: Kamennoye

Asplanchna sp.: Munankilampi, Devichya Lamba

Family *Lecanidae*

Lecane (s. str.)(s. str.) *luna* (Muller, 1776): Vangozero and Putkozero

L. (Monostyla) lunaris (Ehrenberg, 1832): Padmozero, Putkozero and Chuzhmozero

Family *Proalidae*

Proales sp.: Shuezero (?)

Family *Mytilinidae*

Lophocharis oxysternon (Gosse, 1851): Rivers: B. Vanruchei

Family *Euchlanidae*

Euchlanis dilatata Ehrenberg, 1832: Vangozero, Vodlozero, Kosmozero, Padmozero, Putkozero and Yandomozero

E. alata Voronkov, 1911: Shuezero

E. lyra Hudson, 1886: B. Vanruchei

E. lyra lyra Hudson, 1886: Shuezero

E. triquetra Ehrenberg, 1838: Kosmozero, Putkozero and Shuezero. Rivers: B. Vanruchei, Ileksa, Kem and Nizhma

Euchlanis sp.: Rivers: Kem, Kyatka, Myagreka, Sig, Suma, Shuya

Family *Brachionidae*

Brachionus sp.: V. Ladvo and Sumozero. Rivers: Suma

Keratella cochlearis (Gosse, 1851): Vangozero, Vodlozero, Zadneye, Ik, Kamennoye, Kerazhozero, Kosmozero, V. Ladvo, N. Ladvo, Kopozero, Luzskoye, Maria-Sheleka, Melnichnoye 1 and 2, Mogzhozero, Monastyrskoye, Nelmozero, Novgudozero, Nosovskoye, Paanajärvi, Padmozero, Pulozero, Putkozero, Saarijärvi, Sarsajärvi, Sudno, Sumozero, Tolvajärvi, Ukhtozero, Chikshozero, Chuzhmozero, Chukozero, Shuezero, Shchuchya Lamba and Yandomozero. Rivers: Ileksa, Kem and Ropruchei

K. cochlearis hispida (Lauterborn): Kalgachinskoye

K. hiemalis Carlin, 1943: Kamennoye

K. quadrata (Muller, 1786): Kosmozero, Paanajärvi, Putkozero, Sudno, Sumozero, Chuzhmozero and Yandomozero. Rivers: Kem and Suma

Kellicottia longispina (Kellicott, 1879): Ala-Tolvajärvi, Vangozero, Vodlozero, Devichya Lamba, Zadneye, Ik, Kamennoye, Kangasjärvi, Kosmozero, Kopozero, Kylajärvi, V. Ladvo, S. Ladvo, N. Ladvo, Luzskoye, Maria-Sheleka, Melnichnoye 1 and 2, Nelmozero, Novgudozero, Nosovskoye, Monastyrskoye, Paanajärvi, Padmozero, Pieni-Kuohajärvi, Pulozero, Putkozero, Saarijärvi, Sarsajärvi, Sonkusjärvi, S. Vazha, Sudno, Sumozero, Suuri-Kuohajärvi, Sarkijärvi, Saynejärvi, Tolvajärvi, Tuulos, Ukhtozero, Chikshozero, Chuzhmozero, Chukozero, Shuezero, Shchuchya Lamba, Yla-Tolvajärvi, Jurikkajärvi and Yandomozero. Rivers: Vonga, Ileksa, Kem, Kopruchei, Letnyaya, Pongoma, Suma, Khlebnaya and Shuya

Notholca cinetura Skorikov, 1914: Pulozero and Shuezero

N. labis limnetica Levander, 1901: Shuezero

Order *Monimotrochida*

Family *Conochilidae*

Conochilus hippocrepis (Schrank, 1803): Ala-Tolvajärvi, Monastyrskoye. Novgudozero, Suuri-Kuohajärvi and Tuulos. Rivers: Unduksa

C. unicornis Rousselet, 1892: Ala-Tolvajärvi, Vangozero, Vodlozero, Devichya Lamba, Kamennoye, Kangasjärvi, Kopozero, Kosmozero, V. Ladvo, S. Ladvo, N. Ladvo, Maria-Sheleka, Melnichnoye 2, Mogzhozero, Paanajärvi, Padmozero, Pieni-Kuohajärvi, Pulozero, Putkozero, Sarsajärvi, S. Vazha, Sudno, Sumozero, Suuri-Kuohajärvi, Sarkijärvi, Tuulos, Ukhtozero, Chuzhmozero, Chukozero, Shuezero, Shchuchya Lamba, Jula-Tolvajärvi, Jurikkajärvi and Yandomozero. Rivers: Suma and Shuya

*Conochilus sp.*sp.: Ik. Rivers: Ileksa and Kopruchei

Family *Filiniidae*

Filinia terminalis (Plate, 1886): Shuezero

F. longiseta (Ehrenberg, 1834): Vodlozero, Zadneye, Kalgachinskoye, Kerazhozero, Paanajärvi, Padmozero, Putkozero, Chuzhmozero, Chikshozero and Yandomozero

Filinia sp.: Kamennoye

Order *Paedotrochida*

Family *Collothecidae*

Collotheca sp.: Kamennoye and Shuezero

Class *Crustacea*

Copepoda

Suborder *Calanoida*

Family *Centropagidae*

Limnocalanus macrurus Sars,1863: Vangozero, Maria-Sheleka, Paanajärvi ?, Putkozero and Sudno

Family *Diaptomidae*

Eudiaptomus gracilis (Sars, 1863): Ala-Tolvajärvi, Vangozero, Kamennoye, Kangasjärvi, Kosmozero, V. Ladvo, S. Ladvo, N. Ladvo, Maria-Sheleka, Paanajärvi, Padmozero, Pieni-Kuohajärvi, Pulozero, Putkozero, Saarijärvi, Sarsajärvi, Sonkusjärvi, Sudno, Suuri-Kuohajärvi, Sumozero, Sarkijärvi, Saynejärvi, Tolvajärvi, Tuulos, Chuzhmozero, Shuezero, Jula-Tolvajärvi, Jurikkajärvi and Yandomozero. Rivers: Kem, Kyatka, Suma, Unduksa and Shuya

E. graciloides (Lilljeborg, 1888): Vangozero, Vodlozero, Devichya Lamba, Zadneye, Ik, Kamennoye, Kalgachinskoye, Kalivo, Kerazhozero, Kopozero, Kylajärvi, Kosmozero, Luzskoye, Melnichnoye 1 and 2, Mogzhozero, Monastyrskoye, Munankilampi, Mustakivilampi, Nelmozero, Nogvudozero, Nosovskoye, Padmozero, Pieni-Kuohajärvi, Putkozero, Sonkusjärvi, S. Vazha, Sumozero, Sudno, Tuulos, Ukhtozero, Chikshozero, Chukozero, Shchuchya Lamba and Yandomozero. Rivers: Ileksa and Kopruchei

Family *Temoridae*

Eurytemora lacustris (Poppe, 1887): Kamennoye, Maria-Sheleka, Paanajärvi, Sudno, Sumozero, Tuulos and Shuezero. Rivers: Kem

Heterocope appendiculata Sars, 1863: Ala-Tolvajärvi, Vangozero, Zadneye, Ik, Kangasjärvi, Kamennoye, Kopozero, Kosmozero, V. Ladvo, Maria-Sheleka, Monastyrskoye, Mustakivilampi, Novgudozero, Paanajärvi, Pieni-Kuohajärvi, Pulozero, Putkozero, Saarijärvi, Sarsajärvi, Sudno, Sumozero, Suuri-Kuohajärvi, Tuulos, Chuzhmozero, Shuezero, Shchuchya Lamba, Jula-Tolvajärvi and Jurikkajärvi. Rivers: Ileksa, Unduksa and Shuya

Suborder *Cyclopoida*

Family *Cyclopidae*

Macrocyclops fuscus (Jurine, 1820): Putkozero. Rivers: Suma

M. distinctus (Richard, 1887): Putkozero

M. albidus (Jurine, 1820): Paanajärvi, Sumozero, Sarkijärvi, Chikshozero, Chukozero, Shchuchya Lamba and Yandomozero. Rivers: B. Vanruchei

Macrocyclops sp.: Zadneye, S. Ladvo and Shchuchya Lamba

Eucyclops serrulatus (Fischer, 1851): Paanajärvi and Padmozero. Rivers: Kem

=*E. serrulatus var. proximus* (Lill.): Padmozero

E. macruroides (Lilljeborg, 1901): Putkozero and Shchuchya Lamba. Rivers: Ileksa and Kopruchei

E. macrurus (Sars, 1863): Kosmozero, Padmozero, Putkozero, Shuezero and Chuzhmozero

Eucyclops sp.: Munankilampi, Paanajärvi and Sudno

Paracyclops fimbriatus fimbriatus (Fischer, 1853)

=*Paracyclops fimbriatus* (Fischer): Vangozero, Kosmozero, Maria-Sheleka, Paanajärvi, Padmozero, Putkozero, Sudno, Sumozero, Chuzhmozero and Yandomozero

P. affinis (Sars, 1863): Padmozero and Pieni-Kuohajärvi. Rivers: Kem

Paracyclops sp.: Jurikkajärvi. Rivers: Shuya

Cyclops strenuus strenuus Fischer, 1851

=*Cyclops strenuus* Fischer:Ala-Tolvajärvi, V. Ladvo and N. Ladvo, Kamennoye, Kangasjärvi, Kosmozero, Paanajärvi, Padmozero, Pieni-Kuohajärvi, Pulozero, S. Vazha, Saarijärvi, Sarsajärvi, Sonkusjärvi, Sumozero, Suuri-Kuohajärvi, Tolvajärvi, Chuzhmozero, Shuezero, Shchuchya Lamba, Jula-Tolvajärvi, Jurikkajärvi and Yandomozero. Rivers: Keret, Suma and Shuya

C. scutifer scutifer Sars, 1863

=*C. scutifer* Sars: Devichya Lamba, Kamennoye, Kosmozero, Mustakivilampi, Paanajärvi, Saarijärvi, Sudno, Sumozero, Chuzhmozero and Yandomozero. Rivers: Kem

C. vicinus vicinus Uljanin, 1875

=*C. vicinus* Uljanin: Vangozero, Kosmozero, Padmozero, Putkozero, Sumozero, Shuezero, Shchuchya Lamba and Yandomozero. Rivers: Kem, Suma and Shuya

C. insignis Claus, 1857: Kosmozero and Yandomozero

C. colensis Lilljeborg, 1901: Melnichnoye 1

Cyclops sp.: Vodlozero, S. Ladvo, Munankilampi, Sarkijärvi and Saynejärvi. Rivers: Gridina, Kalga, Kuzema, Letnyaya, Nizhma, Pongoma and Khlebnaya

Megacyclops viridis (Jurine, 1820)

=*Acanthocyclops viridis* (Jur.): Vangozero, Kosmozero, Monastyrskoye, Novgudozero, Paanajärvi, Padmozero, Pulozero, Putkozero and Sumozero. Rivers: Ileksa

M. gigas (Claus, 1857)

=*A. gigas* (Claus): Paanajärvi and Pulozero

Acanthocyclops vernalis (Fischer, 1853): Padmozero, Pulozero, Putkozero, Sumozero and Shuezero. Rivers: Kem and Keret

Acanthocyclops sp.: Ala-Tolvajärvi, Vodlozero, Devichya Lamba, V. Ladvo, S. Ladvo, N. Ladvo, Ik, Kopozero, Kylajärvi, Maria-Sheleka, Monastyrskoye, Novgudozero, Nosovskoye, S. Vazha, Saynejärvi, Paanajärvi, Tuulos and Jula-Tolvajärviaa. Rivers: Kem, Kopruchei, Nyukhcha and Suma

Diacyclops languidoides languidoides (Lilljeborg, 1901)

=*Acanthocyclops languidoides* (Lill.): Vangozero, Monastyrskoye, Novgudozero, Paanajärvi and Sudno

D. nanus nanus (Sars, 1863)

=*Acanthocyclops nanus* (Sars): Vangozero, Kosmozero, Padmozero, Saarijand Sumozero. Rivers: Shuya

Cryptocyclops bicolor bicolor (Sars, 1863)

=*Microcyclops bicolor* (Sars): Vangozero

Mesocyclops leuckarti (Claus, 1857): Ala-Tolvajärvi, Vangozero, Vodlozero, Devichya Lamba, Zadneye, Ik, Kamennoye, Kerazhozero, Kopozero, Kosmozero, Kylajärvi, S. Ladvo, N. Ladvo, Luzskoye, S. Vazha, Maria-Sheleka, Melnichnoye 2, Mogzhozero, Monastyrskoye, Munankilampi, Nelmozero, Nelmozero, Novgudozero, Nosovskoye, Paanajärvi, Padmozero, Pieni-Kuohajärvi, Pulozero, Putkozero, Saarijärvi, Sarsajärvi, Sonkusjärvi, Sudno, Sumozero, Suuri-Kuohajärvi, Saynejärvi, Tolvajärvi, Ukhtozero, Chikshozero, Chuzhmozero, Chukozero, Shuezero, Shchuchya Lamba, Jula-Tolvajärvi, Jurikkajärvi and Yandomozero. Rivers: B. Vanruchei, Ileksa, Kem, kolezhma, Kopruchei, Myagreka, Nizhma, Suma and Shuya

Thermocyclops oithonoides (Sars, 1863)

=*Mesocyclops oithonoides* (Sars): Ala-Tolvajärvi, Vangozero, Devichya Lamba, Zadneye, Kalivo, Kamennoye, Kalgachinskoye, Kangasjärvi, Kerazhozero, Kosmozero, Kylajärvi, V. Ladvo, S. Ladvo, N. Ladvo, Mogzhozero, Nelmozero, Nosovskoye, S. Vazha, Maria-Sheleka, Paanajärvi, Padmozero, Pieni-Kuohajärvi, Pulozero, Putkozero, Saarijärvi, Sarsajärvi, Sonkusjärvi, Sumozero, Suuri-Kuohajärvi, Sarkilampi, Sudno, Saynejärvi, Tuulos, Chikshozero, Chuzhmozero, Chukozero, Shuezero, Shchuchya Lamba, Yla-Tolvajärvi, Jurikkajärvi and Yandomozero. Rivers: Vonga, Kem, Kolezhma, Myagreka, Nizhma, Nyukhcha, Sig, Suma, Unduksa and Shuya

Thermocyclops crassus (Fischer, 1853)

=*Mesocyclops crassus* (Fischer): Vodlozero, Ik, Kopozero, Kylajärvi, Luzskoye, Melnichnoye 2, Monastyrskoye, Novgudozero and Chukozero. Rivers: B. Vanruchei, Ileksa and Kopruchei

Cladocera

Order *Daphniiformes*

Family *Sididae*

Sida crystallina crystallina (O.F.Muller, 1776)

=*Sida crystallina* (O.F.Muller): Vangozero, Ik, Kamennoye, Kosmozero, Maria-Sheleka, Monastyrskoye, Novgudozero, Paanajärvi, Padmozero, Pulozero, Putkozero, Sonkusjärvi, Saynejärvi, Sudno, Chuzhmozero, Shuezero, Shchuchya Lamba, Jurikkajärvi and Yandomozero. Rivers: B. Vanruchei, Ileksa, Kem, Keret, Kopruchei, Suma and Shuya

Limnosida frontosa Sars, 1862: Ala-Tolvajärvi, Vangozero, Vodlozero, Zadneye, Ik, Kamennoye, Kerazhozero, Kopozero, Kosmozero, Luzskoye, Melnichnoye 1, Mogzhozero, Monastyrskoye, Nelmozero, Novgudozero, Nosovskoye, Pieni-Kuohajärvi, Pulozero, Putkozero, Saarijärvi, Sarsajärvi, Sumozero, Suuri-Kuohajärvi, Ukhtozero, Chikshozero, Chuzhmozero, Shuezero, Jula-Tolvajärvi and Jurikkajärvi. Rivers: Ileksa, Suma and Shuya

Diaphanosoma brachyurum s. str.

=*Diaphanosoma brachyurum* (Lievin): Ala-Tolvajärvi, Vangozero, Vodlozero, Devichya Lamba, Zadneye, Ik, Kalgachinskoye, Kamennoye, Kangasjärvi, Kopozero, Kosmozero, Luzskoye, Melnichnoye 1, Mogzhozero, Monastyrskoye, Novgudozero, Nosovskoye, Paanajärvi, Padmozero, Pieni-Kuohajärvi, Pulozero, Putkozero, Sarsajärvi, Sumozero, Suuri-Kuohajärvi, Sudno, Ukhtozero, Chikshozero, Chuzhmozero, Chukozero, Shuezero, Shchuchya, Saynejarv,i Lamba, Yla-Tolvajärvi, Jurikkajärvi and Yandomozero. Rivers: B. Vanruchei, Ileksa, Kem, Kopruchei, Suma and Shuya

Latona setifera (O.F.Muller, 1776): Sumozero and Chuzhmozero

Family *Holopedidae*

Holopedium gibberum Zaddach, 1855: Ala-Tolvajärvi, Vangozero, Vodlozero, Devichya Lamba, Kamennoye, Kopozero, Kosmozero, Kylajärvi, V. Ladvo, N. Ladvo, Maria-Sheleka, Melnichnoye 2, Paanajärvi, Pieni-Kuohajärvi, Pulozero, Sonkusjärvi, S. Ladvo, Saarijärvi, Sarsajärvi, Sudno, Sumozero, Suuri-Kuhajärvi, Sarkilampi, Tolvajärvi, Tuulos, Ukhtozero, Chuzhmozero, Shuezero, Shchuchya Lamba, Jula-Tolvajärvi and Jurikkajärvi. Rivers: Kem, Kopruchei, Suma, Unduksa and Shuya

Family *Daphniidae*

Daphnia (Daphnia) pulex Leydig, 1860

=*Daphnia pulex* (De Geer): Kamennoye

D. (Daphnia) longispina O.F.Muller, 1785

=*D. longispina* O.F.Muller: Ala-Tolvajärvi, Ik, Saarijärvi, Sarsajärvi, Sumozero, Yla-Tolvajärvi, Jurikkajärvi and Yandomozero. Rivers: Ileksa and Keret

D. (Daphnia) hyalina Leydig, 1860

=*D. hyalina* Leydig: Putkozero, Kosmozero and Yandomozero

=*D. hyalina pellucida* O. F. Muller: Yandomozero

=*D. longispina hyalina* (Leydig): Zadneye, Kamennoye, Kopozero, Kosmozero, Luzskoye, Mogzhozero, Monastyrskoye, Novgudozero, Pieni-Kuohajärvi, Putkozero, Sarsajärvi, Suuri-Kuohajärvi, Ukhtozero, Chuzhmozero, Chikshozero, Shuezero and Yandomozero. Rivers: Kem

D. (Daphnia) galeata G. O. Sars, 1864

=*D. hyalina galeata* G. O. Sars: Vangozero, Kosmozero, Putkozero, Chuzhmozero and Yandomozero

D. (Daphnia) cucullata G.O. Sars, 1862

=*D. cucullata Sars*: Ala-Tolvajärvi, Vangozero, Vodlozero, Ik, Kosmozero, Monastyrskoye, N. Ladvo, Novgudozero, Paanajärvi, Putkozero, Chuzhmozero and Yandomozero. Rivers: Ileksa

=*D. cucullata berolinensis* Schoedler: Padmozero and Yandomozero

=*D. cucullata kahlbergensis* Schoedler: Putkozero, Chuzhmozero and Yandomozero

D. (Daphnia) longiremis G.O. Sars, 1862

=*D. longiremis* Sars: Vangozero, Kamennoye, Kosmozero, Padmozero and Putkozero

D. (Daphnia) cristata G.O. Sars, 1862

=*D. cristata* Sars: Ala-Tolvajärvi, Vangozero, Vodlozero, Zadneye, Ik, Kalivo, Kalgachinskoye, Kamennoye, Kangasjärvi, Kerazhozero, Kopozero, Kosmozero, Kylajärvi, V. Ladvo, S. Ladvo, N. Ladvo, Luzskoye, Maria-Sheleka, Melnichnoye 1 and 2, Mogzhozero, Monastyrskoye, Munankilampi, Mustakivilampi, Nelmozero, Novgudozero, Nosovskoye, Paanajärvi, Padmozero, Pieni-Kuohajärvi, Pulozero, Putkozero, Saarijärvi, Sarsajärvi, Sonkusjärvi, S. Vazha, Sudno, Sumozero, Suuri-Kuohajärvi, Sarkijärvi, Saynejärvi, Tolvajärvi, Tuulos, Chikshozero, Chuzhmozero, Chukozero, Shuezero, Shchuchya Lamba, Yla-Tolvajärvi, Jurikkajärvi and Yandomozero. Rivers: B. Vanruchei, Ileksa, Kem, Kolezhma, Kopruchei, Suma, Unduksa and Shuya

=*D. cristata cristata typica* G. O. Sars: Vangozero, Kosmozero, Putkozero and Chuzhmozero

=*D. c. c. cederstromi* Schoedler: Kosmozero, Padmozero, Chuzhmozero and Yandomozero

Simocephalus vetulus (O.F.Muller,1776): Rivers: B. Vanruchei and Kem

S. serrulatus (Koch, 1841): Rivers: Kopruchei

Ceriodaphnia quadrangula (O.F.Muller, 1785): Ala-Tolvajärvi, Vangozero, Devichya Lamba, Kamennoye, Kangasjärvi, Kosmozero, Kylajärvi, Padmozero, Pulozero, Putkozero, Saarijärvi, Sumozero, Sarkijärvi, Shuezero, Shchuchya Lamba, Saynejärvi , Jurikkajärvi and Yandomozero. Rivers: Suma and Shuya

=*C. quadrangula typica* (O.F. Muller): Vangozero, Kosmozero, Padmozero and Yandomozero

C. dubia Richard, 1894

=*C. affinis* Lilljeborg: Kamennoye, Maria-Sheleka, Sarsajärvi , Sumozero, Jurikkajärvi and Yandomozero

C. reticulata (Jurine, 1820): Padmozero and Putkozero. Rivers: Keret

=*C. reticulata kurzi* Stingelin: Padmozero and Putkozero

C. pulchella Sars, 1862: Vangozero, Kalgachinskoye, Kopozero, Kosmozero, Melnichnoye 1, Mogzhozero, Monastyrskoye, Novgudozero, Putkozero, Ukhtozero, Shuezero and Yandomozero. Rivers: B. Vanruchei, Ileksa, Kalga, Kem, Kopruchei, Letnyaya, Myagreka, Nizhma, Sig, Suma, Khlebnaya and Shuya

Ceriodaphnia sp.: Paanajärvi

Scapholeberis mucronata (O.F.Muller,1776): Vangozero, Kamennoye, Monastyrskoye, Novgudozero, Paanajärvi, Padmozero, Putkozero, Sumozero and Shuezero. Rivers: Ileksa, Kem, Keret, Kopruchei, Kyatka and Suma

=*S. mucronata cornuta* Schoedler: Putkozero

Family *Macrothricidae*

Ophryoxus gracilis gracilis Sars, 1862

=*Ophryoxus gracilis* Sars: Ala-Tolvajärvi, Devichya Lamba, Kamennoye, Kosmozero, S. Ladvo, Pulozero, Putkozero, Saarijärvi, Sonkusjärvi, Tuulos, Shuezero. Shchuchya Lamba and Saynejärvi. Rivers: Ileksa, Kem, Keret, Suma and Shuya

Family *Ilyocryptidae*

Ilyocryptus sordidus (Lievin, 1848): Sumozero and Tuulos

I. acutifrons Sars, 1862: Rivers: Myagreka

Family *Chydoridae*

Eurycercus lamellatus (O.F.Muller,1785): Ala-Tolvajärvi, Kosmozero, S. Ladvo, Maria-Sheleka, Padmozero, Putkozero, Saarijärvi, Sarkijärvi, Shchuchya Lamba and Jurikkajärvi. Rivers: Ileksa, Kem, Keret, Suma and Khlebnaya

Pleuroxus aduncus (Jurine, 1820): Rivers: Kolezhma and Suma

P. uncinatus Baird, 1850: Rivers: Kem

P.truncatus truncatus (O.F. Muller, 1785)

=*Peracantha truncata* (O.F.Muller): Kosmozero, Saarijärvi and Shchuchya Lamba. Rivers: Ileksa, Kem, Keret, Kopruchei, Suma

Alonella nana (Baird, 1850): Vangozero, Kamennoye, Kosmozero, Padmozero, Putkozero, S. Ladvo, Shuezero and Yandomozero. Rivers: Kem and Suma

A. exigua (Lilljeborg, 1853): Vangozero, Putkozero and Sumozero. Rivers: Kem

A. excisa (Fischer, 1854): Vangozero, Padmozero and Putkozero

Disparalona rostrata rostrata (Koch, 1841)

=*Rhynchotalona rostrata* (Koch): Vangozero, Kosmozero, Nelmozero, Padmozero and Putkozero. Rivers: Ileksa and Kolezhma

Chydorus sphaericus (O.F.Muller, 1785): Ala-Tolvajärvi, Vangozero, Vodlozero, Zadneye, Ik, Kalivo, Kalgachinskoye, Kamennoye, Kerazhozero, Kopozero, Kosmozero, V. Ladvo, S. Ladvo, N. Ladvo, Luzskoye, Maria-Sheleka, Melnichnoye 1 and 2, Mogzhozero, Monastyrskoye, Nelmozero, Novgudozero, Nosovskoye, Padmozero, Pulozero, Putkozero, Saarijärvi, Sonkusjärvi, S. Vazha, Sudno, Sumozero, Saynejärvi, Tolvajärvi, Ukhtozero, Chikshozero, Chuzhmozero, Chukozero, Shuezero, Shchuchya Lamba, Jula-Tolvajärvi, Jurikkajärvi and Yandomozero. Rivers: B. Vanruchei, Ileksa, Kem, Keret, Kolezhma, Kopruchei, Kuzema, Kyatka, Myagreka, Nyukhcha, Sig, Suma, Khlebnaya and Shuya

C. sphaericus alexandrovi Poggenpol, 1874: Yandomozero

C. sphaericus caelatus Schoedler, 1862: Kosmozero

C. ovalis Kurz, 1875

=*C. latus* Sars: Vangozero and Shuezero

C. piger Sars, 1862: Devichya Lamba, Kamennoye, Kangasjärvi and Pieni-Kuohajärvi

C. gibbus Sars, 1891: Kylajärvi

Pseudochydorus globosus globosus (Baird, 1843)

=*C. globosus* Baird: Kosmozero, Kylajärvi and Tuulos. Rivers: Kem

Alona quadrangularis (O.F.Muller, 1785): Vanchozero, Melnichnoye 2, Paanajärvi, Sudno, Sumozero and Shuezero. Rivers: Ileksa, Kem, Ropruchei, Suma, Unduksa and Shuya

A. costata Sars, 1862: Vangozero, Kosmozero, Paanajärvi, Padmozero, Pulozero, Putkozero, Sudno and Shuezero

A. guttata Sars, 1862: Padmozero, Putkozero, Shuezero and Yandomozero. Rivers: B. Vanruchei, Kem, Nizhma, Pongoma and Khlebnaya

A. rectangula Sars, 1862: Kamennoye, Paanajärvi, Putkozero and Shuezero. Rivers: Nyukhcha and Shuya

Acroperus harpae (Baird, 1834): Vangozero, V. Ladvo, Kamennoye, Kosmozero,Padmozero, Pulozero, Putkozero, Saarijärvi, Sarsajärvi, Sumozero, Sarkijärvi, Shuezero, Chuzhmozero and Yandomozero. Rivers: Ileksa, Kem, Keret, Kolezhma, Nyukhcha, Suma and Shuya

A. elongatus elongatus (Sars, 1862)

=*Alonopsis elongata* Sars: Ala-Tolvajärvi, Vangozero, Devichya Lamba, Kamennoye, Kosmozero, V. Ladvo, Maria-Sheleka, Mustakivilampi, Paanajärvi, Padmozero, Pieni-Kuohajärvi, Pulozero, Putkozero, Saarijärvi, Sarsajärvi, Sonkusjärvi, Sudno, Sumozero, Saynejärvi, Tuulos, Chuzhmozero, Shuezero, Shchuchya Lamba, Jurikkajärvi and Yandomozero. Rivers: Ileksa, Kem, Keret, Kuzema, Nizhma, Suma and Shuya

Camptocercus rectirostris Schoedler,1862: Ala-Tolvajärvi, Chikshozero and Jula-Tolvajärvi. Rivers: Kem

Graptoleberis testudinaria (Fischer, 1851): Kosmozero, Padmozero and Putkozero. Rivers: Kem and Nizhma

Leydigia leydigi (Schoedler, 1863): Padmozero and Putkozero. Rivers: Suma

Biapertura affinis affinis (Leydig, 1860)

=*Alona affinis* Leydig: Devichya Lamba, Monastyrskoye, Novgudozero, Chikshozero, Shchuchya Lamba and Yandomozero. Rivers: Kem

Rhynchotalona falcata (Sars, 1862): Vangozero, Padmozero, Saarijärvi, S. Ladvo, Sumozero and Tuulos. Rivers: Kem and Nyukhcha

Monospilus dispar Sars, 1862: Pulozero

Family *Bosminidae*

Bosmina (Bosmina) longirostris (O.F.Muller, 1785)

=*Bosmina longirostris* (O.F.Muller): Ala-Tolvajärvi, Vangozero, Kalgachinskoye, Kamennoye, Kosmozero, V. Ladvo, S. Ladvo, N. Ladvo, Mogzhozero, Monastyrskoye, Novgudozero, S. Vazha, Maria-Sheleka, Paanajärvi, Padmozero, Pulozero, Putkozero, Sarkijärvi, Sarsajärvi, Sumozero, Sudno, Tuulos, Chuzhmozero, Shuezero, Shchuchya Lamba, Saynejärvi and Yandomozero. Rivers: B. Vanruchei, Vonga, Ileksa, Gridina, Kem, Kopruchei, Suma and Shuya

B. (Eubosmina) longispina Leydig, 1860.

=*B. longispina* Leydig: Vangozero, Maria-Sheleka, Padmozero, Pulozero, Sumozero, Tuulos, Shuezero and Yandomozero. Rivers: Kem

B. (Eubosmina) coregoni Baird, 1857

=*B. obt. obtusirostris* Sars: Ala-Tolvajärvi, Vangozero, Devichya Lamba, Kalivo, Kamennoye, Kangasjärvi, Kylajärvi, Kopozero, Kosmozero, V. Ladvo, S. Ladvo, Novgudozero, Nosovskoye, Maria-Sheleka, Monastyrskoye, Munankilampi, Mustakivilampi, Paanajärvi, Padmozero, Pieni-Kuohajärvi, Pulozero, Putkozero, Saarijärvi, Sarsajärvi, S. Vazha, Sudno, Sumozero, Suuri-Kuohajärvi, Tuulos, Chuzhmozero, Chukozero, Shuezero, Shchuchya Lamba, Yla-Tolvajärvi, Jurikkajärvi and Yandomozero. Rivers: B. Vanruchei, Kem, Keret and Nyukhcha

=*B. obt. lacustris* Sars: Ala-Tolvajärvi, Vangozero, Vodlozero, Kamennoye, Kalgachinskoye, Kangasjärvi, Kosmozero, Kylajärvi, V. Ladvo, N. Ladvo, S. Vazha, Maria-Sheleka, Melnichnoye 1, Munankilampi, Paanajärvi, Padmozero, Pieni-Kuhajärvi, Pulozero, Putkozero, Saarijärvi, Sarsajärvi, Suuri-Kuohajärvi, Sudno, Tolvajärvi, Sonkusjärvi, Sumozero, Tuulos, Ukhtozero, Chuzhmozero, Shuezero, Shchuchya Lamba, Saynejärvi, Yla-Tolvajärvi, Jurikkajärvi and Yandomozero. Rivers: B. Vanruchei, Vonga, Gridina, Ileksa, Kalga, Kem, Keret, Kopruchei, Kuzema, Kyatka, Letnyaya, Nizhma, Pongoma, Sig, Unduksa, Khlebnaya and Shuya

=*B. obt. cisterciensis* Ruhe: Pulozero, Sumozero and Chuzhmozero

=*B. coregoni* Baird: Ala-Tolvajärvi, Vangozero, Kosmozero, Paanajärvi, Pieni-Kuohajärvi, Pulozero, Putkozero, Saarijärvi, Sarsajärvi, Sumozero, Suuri-Kuohajärvi, Tolvajärvi, Chuzhmozero, Shuezero, Yla-Tolvajärvi, Jurikkajärvi and Yandomozero. Rivers: Kem

=*B. coregoni coregoni* (Baird): Kamennoye, Kosmozero, Sumozero and Yandomozero. Rivers: Kem, Suma and Shuya

=*B. coregoni gibbera* (Schoedler): Kamennoye, Monastyrskye, Novgudozero and Sumozero. Rivers: Suma

=*B. coregoni thersites* (Poppe): Pulozero and Sumozero

=*B. coregoni lilljeborgii* (Sars): Zadneye, Vodlozero, Ik, Kopozero, Kosmozero, Luzskoye, Melnichnoye 1, Mogzhozero, Monastyrskoye, Nelmozero, Novgudozero, Nosovskoye, Putkozero, Sumozero, Shuezero, Chikshozero, Chukozero and Yandomozero. Rivers: Ileksa and Kopruchei

=*B. coregoni mixta* Lilljeborg: Vangzero, Kosmozero, Putkozero and Yandomozero

=*B. coregoni mixta lilljeborgi* Sars: Kosmozero, Putkozero and Yandomozero

=*B. coregoni mixta humilis* Lilljeborg: Kosmozero

=*B. coregoni insignis gibberiformes* L.: Putkozero

=*B. coregoni longicornis* Schoedler: Kosmozero and Yandomozero

=*B. kessleri* (Uljanin): Kamennoye, Maria-Sheleka, Paanajärvi, Pulozero, Sudno, Sumozero, Tuulos and Shuezero. Rivers: Kem and Shuya

B. (Eubosmina) crassicornis Lilljeborg, 1887

=*B.crassicornis* (P.E.Muller): Vangozero. Rivers: Suma and Shuya

=*B. c.crassicornis rotundata* Lilljeborg: Vangozero

Order *Polyphemiformes*

Family *Polyphemidae*

Polyphemus pediculus (Linne, 1778): Ala-Tolvajärvi, Vangozero, Devichya Lamba, Kamennoye, Kosmozero, Kylajärvi, V. Ladvo, S. Ladvo, Maria-Sheleka, Melnichnoye 2, Monastyrskoye, Novgudozero, Paanajärvi, Padmozero, Pieni-Kuohajärvi, Pulozero, Putkozero, Saarijärvi, Sarsajärvi, Sudno, Sumozero, Suuri-Kuohajärvi, Sarkijärvi, Tolvajärvi, Tuulos, Chuzhmozero, Chukozero, Shuezero, Shchuchya Lamba, Saynejärvi and Jurikkajärvi. Rivers: Ileksa, Kem, Keret, Kyatka, Nizhma, Suma and Shuya

Family *Cercopagidae*

Bythotrephes longimanus Leydig, 1860: Vangozero, Kamennoye, Melnichnoye 2, Chikshozero, Pulozero and Sumozero

=*B. cederstromii* Schoedler: Kamennoye, Monastyrskoye, Novgudozero, Sumozero, Chuzhmozero and Yandomozero

Order *Leptodoriformes*

Family *Leptodoridae*

Leptodora kindtii (Focke, 1844): Vangozero, Zadneye, Ik, Kamennoye, Kerazhozero, Kopozero, S. Ladvo, Luzskoye, Melnichnoye 2, Mogzhozero, Monastyrskoye, Nelmozero, Novgudozero, Nosovskoye, Paanajärvi, Padmozero, Pulozero, Putkozero, Sudno, Sumozero, Ukhtozero, Chikshozero, Chuzhmozero, Chukozero, Shuezero and Yandomozero. Rivers: Ileksa and Suma

4.4. Macrozoobenthos

4.4.1. Macrozoobenthos of the lakes in protected areas

Introduction. The conservation of the biological diversity of water-based ecosystems has assumed vital importance over recent years. Freshwater ecosystems have been adversely affected by human activities which have led to changes in the structure of communities of freshwater organisms and a consequent decline in their species diversity. Owing to the ever increasing disturbance caused by human activities on the natural state and development patterns of aquatic biocenoses the need for a thorough anthropogenic study of the biological diversity of these ecosystems has grown significantly over the last few decades.

Lake and riverbed fauna has long been studied in Karelia. The first information on benthic organisms from lakes Onega and Ladoga date as far back as the late 18th century (Ozeretskovsky, 1792). During 1864-1866 lake fauna was studied in the Olonets province by Professor K. F. Kessler of St. Petersburg University (1868). However, it was not until the 1920s that attempts to study Karelian water bodies more systematically were made. Knowledge of bottom fauna greatly advanced through the efforts of I. I. Ioffe (1948), B. M. Aleksandrov (1966), S. V. Gerd (1946, 1949), O. N. Gordeyev (1948), A. A. Zabolotsky (1961, 1964) and V. A. Sokolova (1965). In 1965 a review of Karelian lake fauna appeared which described the habitats of over 1000 benthic species and forms from more than two hundred lakes of various sizes (Lake Fauna of Karelia, 1965).

The main aim of the our study was to record and present the diversity and basic quantitative parameters of macrozoobenthic communities in the lakes of both the existing (Kostomuksha and Kizhi Skerries reserves, Paanajärvi and Vodlozero national parks) and proposed (Kalevala, Tuulos and Koitajoki PNP, Zaonezhye Peninsula) protected areas of the Republic of Karelia.

Methods. Quantitative samples of macrozoobenthos were taken using Ekman-Birge's bottom grab with a sampling area of 225–300 cm^2. A hand net was also used for faunistic studies. The samples were washed through a sieve with a mesh size of 0.3–0.5 mm and preserved in 4% formaldehyde solution. The samples were then sorted in the laboratory, the animals were grouped into higher systematic units, identified and weighed in wet form to an accuracy of 0.0001 g. The Shannon-Weaver index was used to describe the diversity of the benthic communities (Shannon, 1948). The trophic levels of lakes were calculated according to Kitaev's method (1984).

Results and discussion. On the basis of surveys performed during the period 1989–1999 the lakebed invertebrate fauna of the protected areas of Karelia consists of over 180 taxa (Appendix). Most of these species are of widespread occurrence throughout the paleoarctic region. Lake macrozoobenthos are mostly made up of species of *Oligochaeta, Mollusca* and *Insecta*. The relative proportions of these groups constitute one of the main structural determinants of benthic cenoses. The benthic cenoses of the lakes located in the protected areas are generally dominated in terms of both prolificacy and biomass by *Insecta* such as *Trichoptera*, *Ephemeroptera* and *Diptera*, especially those of the *Chironomidae* family.

Benthic cenoses vary greatly in terms of both population density (from 500 inds./m^2 in lakes Kamennoye and Tuulos to 4500–5300 inds./m^2 in the Kizhi Skerries and the lakes of Zaonezhye) and biomass (from 0.5 g/m^2 in Lake Monastyrskoye to 3.8 g/m^2 in the Kizhi Skerries). The trophic status of lakes largely unaffected by human activities varies from oligotrophic to mesotrophic.

Below we describe the main features of macrozoobenthos in the lakes of protected areas.

Paanajärvi National Park. The invertebrate lakebed fauna of the oligothrophic Lake Paanajärvi comprises fifty-four taxa characteristic of North European water bodies (Ryabinkin, 1993). The majority of species are of entomofauna such as mayflies, caddis flies, stone flies, aquatic *Coleoptera*, alder flies and *Diptera*. The last-mentioned consists mostly of *Chironomidae* larvae (thirty-five species and larval forms – see Appendix). In the littoral and sublittoral zones oligochaetes of the *Naididae* family and molluscs of the *Sphaeridae* family occur in large quantities. The profundal zone is dominated by *Chironomidae* (*Procladius* sp. and *Trissocladius paratatricus*) and the crustaceans *Pallasea quadrispinosa*, *Mysis relicta* and *Monoporeia affinis*. The glacial relict *M. affinis* was found in 60% of samples; it accounts for 25% of overall population size and 30% of biomass of benthos in the profundal zone. The average biomass of macrozoobenthos varies from 0.3 g/m^2 in the profundal zone to 4.0 g/m^2 on the littoral zone. At a depth of ten metres lakebed biocenoses decrease rapidly by a factor of twenty in terms of population density, fifteen times with respect to biomass and threefold in species diversity.

Kostomuksha Strict Nature Reserve. The main water body in the reserve is Lake Kamennoye. In terms of the low prolificacy of macrobenthos it may be classified as an oligotrophic lake. Average numbers of organisms in the littoral zone vary from 150 to 1800 inds./m^2 with biomass ranging from 0.4 to 2.1 g/m^2. The corresponding figures for the profundal zone are 100–800 inds./m^2 and 0.2–1.0 g/m^2, respectively. The benthic communities of Lake Kamennoye consist of more than eighty taxa. As in most Karelian oligotrophic lakes *Chironomidae, Oligochaeta* and Mollusca dominate (see Appendix). The species diversity index fell from 4.18 in 1973 to 3.48 in 1992.

As Lake Kamennoye has not been seriously affected by human activities the structural parameters and quantitative characteristics of its benthic cenoses did not change greatly during the period 1973–1993 (Ryabinkin, 1997).

Kalevala National Park. A study was performed of the qualitative composition and quantitative parameters of lakebed fauna in lakes Sudno, Verkhneye Ladvo, Sredneye Ladvo, Nizhneye Ladvo and Srednyaya Vazha located in the park. These lakes are all typical of the north-taiga zone. Their macrozoobenthos consists of eighteen taxa. The profundal zone is dominated by three major groups, namely, *Oligochaeta, Bivalvia* and *Insecta (Chironomidae).* Shannon index values varied during the study period from 1.06 in Lake Nizhneye Ladvo to 2.68 in Lake Sudno. *Trichoptera, Ephemeroptera, Coleoptera, Odonata, Plecoptera* and various other groups were found in the benthic cenoses of the rocky littoral zones (see Appendix).

Population densities varied from 83 inds./m^2 in Lake Sudno to 2183 inds./m^2 in Lake Srednyaya Vazha while biomass ranged from 0.225 g/m^2 in Lake Nizhneye Ladvo to 1.420 g/m^2 in Lake Srednyaya Vazha.

Tuulos National Park. The lakebed biocenoses of Lake Tuulos located in the centre of the proposed national park was found to consist of thirty-six taxa. Insects, especially *Chironomidae*, provide the most diverse group of fauna (see Appendix). Profundal macrozoobenthos include the larvae of *Chironomidae* (*Procladius* sp., *Sergentia* sp., *Stictochironomus crassiforseps*), *Mollusca* (*Sphaeriidae*) and *Oligochaeta*. The average species diversity index is 2.43. The fauna is more diverse on the sand-mud substrate in the littoral zone of the inlet portion of the lake. Here *Chironomidae, Bivalvia* and *Oligochaeta* may be found as well as the larvae of *Trichoptera* and *Ephemeroptera.* The average population density of zoobenthos in Lake Tuulos is 494 inds./m^2 and average biomass 1.046 g/m^2. The greatest contribution to overall biomass (65.8%) is made by bivalve molluscs of the genus *Euglesa* (65.8%).

Koitajoki National Park. The lakebed invertebrate communities of the lakes of the Koitajoki river system (lakes Tolvajärvi, Jurikkajärvi, Saarijärvi, Jula-Tolvajärvi, Ala-Tolvajärvi, Pieni-Kuohajärvi, Kylajärvi, Kangasjärvi and Sonkusjärvi) are known to contain fifty-seven taxa (see Appendix). This figure is likely to rise considerably following the identification of *Oligochaeta, Bivalvia, Trichoptera, Ceratopogonidae* and other specimens collected. The most diverse group of fauna is made up of the chironomids and consists of twenty-nine species and larval forms. Species of the genera *Tanytarsus, Cladotanytarsus, Pagastiella, Cryptochironomus, Trissocladius,* and *Procladius* etc. are most common.

Communities in the rocky littoral zone are dominated by *Trichoptera***,** *Ephemeroptera* (*Heptagenia* sp.), *Hirudinea* (*Glossiphonia complanata*), *Bivalvia* (*Euglesa* sp.) and *Gastropoda* together with psammophilic forms of Chironomidae (*Cryptochironomus defectus* and *Demicryptochironomus vulneratus*).

A sandy littoral zone overgrown with reed and horsetail (another important type of littoral habitat) is inhabited by a diverse fauna of *Hirudinea, Bivalvia, Crustacea* (*Asellus aquaticus)*, *Oligochaeta (Naididae), Megaloptera* (*Sialis flavelatera)*, *Trichoptera (Limnophilidae), Ephemeroptera, Ceratopogonidae* and *Chironomidae.*

The mud zone contains a much poorer benthos dominated by the larvae of *Chironomidae, Bivalvia* and *Oligochaeta.* In addition to these major groups *Chaoborus crystallinus*, *S. flavelatera*, *C. macrura* and *E. vulgata* contribute significantly to the total biomass.

Shannon diversity index values calculated for the whole lake vary substantially, i.e. from 1.46 in Lake Saarijärvi to 4.29 in Lake Tolvajärvi. Quantitative values of macrozoobenthos also vary considerably: population density from 533 inds./m^2 in Lake Saarijärvi to 5722 inds./m^2 in Lake Sarsajärvi and biomass from 1.02 g/m^2 in Lake Ala-Tolvajärvi to 4.54 g/m^2 in Lake Suuri-Kuohajärvi.

Lakes in the Zaonezhye Peninsula. Earliest information on the lake invertebrate fauna of the Zaonezhye Peninsula dates from the mid 19th century. In 1866 K.F. Kessler identified the relict crustaceans *M. relicta*, *P. quadrispinosa*, *M. affinis* and *Gammaracantus loricatus var. lacustris* in Lake Putkozero (Gerd, 1946). More detailed faunistic studies were conducted and lists of species were drawn up in 1947 and 1963 (Sokolova & Gordeyev, 1965). In all, studies were performed on lakes Putkozero, Ladvozero, Padmozero, Vanchozero and Nizhneye Pigmozero.

According to the results of our studies conducted in 1999, lake benthic cenoses are now known to contain over seventy taxa (see Appendix). Species of *Nematoda, Oligochaeta, Hirudinea, Bivalvia, Gastropoda, Crustacea, Hydracarina, Insecta (Plecoptera, Ephemeroptera, Trichoptera, Heteroptera, Coleoptera* and *Diptera)* are all found. The largest numbers of species are associated with the group *Mollusca* and with the insect orders *Ephemeroptera, Trichoptera* and *Diptera,* especially the *Chironomidae* family.

The lakes studied differ in terms of species diversity. Thus, the lakebed invertebrate fauna of Lake Putkozero comprises 40 taxa, Lake Vanchozero 32 taxa, Lake Kosmozero also 32 taxa, while in lakes Yandomozero and Padmozero we found only 13 species each. Shannon index values vary from 2.91 (Lake Yandomozero) and 3.03 (Lake Padmozero) to 3.66 (Lake Putkozero). This last-mentioned value represents a fairly high degree of biodiversity of lakebed biocenoses.

Average biomass values of benthos vary considerably, i.e. from 10.69 g/m^2 in Lake Yandomozero, which is most affected by eutrophication, to 1.30 g/m^2 in Lake Kosmozero. In most lakes the largest single group consists of the larvae of *Chironomidae,* which accounts for between 47% and 93% of biomass. At the same time, the respective contributions of different groups to the biomass of benthic cenoses are highly variable. The benthos of Lake Yandomozero is dominated by *Chironomidae* and *Bivalvia,* in Lake Padmozero by *Chironomidae, Trichoptera* and *Oligochaeta,* in Lake Kosmozero by *Chironomidae* and *Megaloptera,* and in Lake Putkozero by *Ephemeroptera* and *Crustacea.*

The above lakes differ morphologically, hydrologically and hydrochemically. They all have well-developed littoral zones which are well heated during the summer season because the climate in these areas is not much colder than in Priladozhye. This, together with the absence of any well-developed industrial infrastructure in their catchment areas, contributes to the relatively high biodiversity of their benthic cenoses.

It is our contention that special attention should be paid to the conservation of the natural biocenoses of Lake Putkozero where a highly diverse lakebed invertebrate fauna and an intact complex of relict crustaceans have remained unchanged since the previous study was conducted almost thirty years.

Kizhi Skerries, Lake Onega. Rapidly warming shallow-water zones often with well developed higher aquatic vegetation, poor water exchange with open lake zones and a favourable oxygen system are conducive to the development of a varied lakebed fauna comprising over forty taxa.

Lakebed cenoses are dominated in terms of both prolificacy and biomass by the larvae of *Chironomidae*. The dominant complex consists of twenty-eight species and larval forms, most of which (75%) belong to the family *Chironominae*. The most populous forms are eurybiont larvae of the genus *Procladius* (870 inds./m^2), *Polypedilum scalaenum* (270 inds./m^2) and *Chironomus* sp. (260 inds./m^2). In addition to these the dominant complex contains the oxyphilic species *Stempellina bausei, Harnishia fuscimana* and *Paralauterborniella nigrochalteralis*. Lesser populations of *Constempellina brevicosta, Pagastiella orophila* and *Micropsectra lobatifrons* also occur. The highest overall population density and biomass values (up to 7500 inds./m^2 and 4.5 g/m^2) of the larval complex was recorded in the autumn. Alongside *Chironomidae, Oligochaeta* comprise a major constituent of the macrozoobenthos. In the autumn they generally account for no more than 30% of the biomass of all benthic cenoses. However, in the spring when the imago of heterotopic organisms emerge they contribute as much as 70% of total prolificacy and biomass. The absolute abundance and biomass values of *Oligochaeta* are 4200 inds./m^2 and 2.2 g/m^2. *Bivalves*, *Crustacea* (*M. affinis)*, *Hydrachnellae*, *Trichoptera, Ephemeroptera* and *Ceratopogonidae* are less common.

The skerry zones are very similar to one another in terms of faunistic composition and species groups of macrobenthos. Their biocenotic similarity coefficients vary from 0.42 to 0.61. The average population density and biomass value of macrozoobenthos in the skerries during the warm season are estimated at 4500 inds./m^2 and 3.8 g/m^2. On grey-green mud deposits in a small bay east of Kizhi Island a community dominated in terms of biomass by the larvae of *Chironomus* sp. is worthy of note. This pelophilic form typical of organic-rich sediments is most prolific here (800 inds./m^2).

The quantitative characteristics and qualitative composition of lakebed cenoses in the skerries correspond to those of mesotrophic lakes. Dominant communities are composed of eurybiont species and forms displaying a broad spectrum of ecological requirements.

Vodlozero National Park. Vodlozero National Park located in the Ileksa River basin is one of the few such areas in North Europe practically unaffected by human activities. The largest water body in the basin, Lake Monastyrskoye is home to fifty-six species or groups of macrozoobenthos.

The majority of macrobenthos species are those of insect larvae, the fauna of *Chironomidae* being the most diverse (thirty-two species and forms). These dominate in terms of both prolificacy and biomass (average of 65% of overall prolificacy and almost 70% of total biomass). *Oligochaeta* contribute an average of 30% to prolificacy and over 20% to biomass. *Limnochironomus tener, Stempellinella minor* and *Tanytarsus gr. gregarius*, along with larvae of the genus *Cladotanytarsus, Stempellina subglabripennis* and *Polypedilum scalaenum*, are all encountered on mud in moderately deep and deep portions of the lake. Predatory forms are represented by species of the genus *Procladius* and *C. defectus*.

While overall population density is relatively high (2800 inds./m^2), biomass is only 0.5 g/m^2. This is due to both the small size of individuals of the dominant Tanytarsini species and the prevalence of early instars in populations during the study period.

The trophic status of Lake Monastyrskoye varies from mesotrophic to eutrophic The available data suggest that Lake Monastyrskoye is well suited to the study of the functioning of communities in a naturally evolving water body (Vislyanskaya et al., 1995).

Conclusion. It should be noted that the data provided by the first preliminary study of lakebed invertebrates in most of the water bodies in the protected areas of Karelia is too incomplete for an accurate assessment of the diversity of benthic cenoses and that further studies are needed. Although the lakes of Karelia have been studied over a long period of time there are still many lakes of considerable interest (e.g. the deep-water lakes in Middle Karelia) that were last studied over forty years ago or, indeed, which have not been studied at all.

Appendix

Taxonomic composition of lake macrozoobenthos in the protected areas of Karelia

Taxa*	1	2	3	4	5	6	7	8
Hydroidea								
Hydra vulgaris Pall.	–	–	–	+	–	–	–	–
Turbellaria	–	–	–	+	–	–	–	–
Nematoda	+	+	+	+	+	+	+	+
Oligochaeta	+	+	+	+	+	+	+	+
Tubifex tubifex (Muller)	–	+	–	–	–	–	–	–
Spirosperma ferox Eisen	–	+	–	–	–	–	–	–
Lumbriculus variegatus (Muller)	–	+	–	–	–	–	–	–
Hirudinea	–	+	–	–	+	–	–	–
Piscicola geometra (Linne)	–	–	–	–	–	–	+	–
Glossiphonia complanata (Linne)	–	–	+	–	–	–	–	–
Helobdella stagnalis (Linne)	–	–	–	+	–	–	–	–
Erpobdella octoculata (Linne)	–	+	+	–	–	–	–	–
Acari	–	+	+	+	–	+	+	–
Crustacea	–	+	+	+	+	+	+	–
Isopoda	–	–	+	+	+	–	–	–
Asellus aquaticus Linne	–	–	+	+	+	–	–	–
Amphipoda	–	+	–	–	+	+	+	–
Gammarus lacustris Sars	–	+	–	–	–	–	–	–
Monoporeia affinis Lindstr.	–	–	–	–	+	+	+	–
Pallasea quadrispinosa Sars	–	–	–	–	+	–	–	–
Mysidacea	–	–	–	–	–	–	+	–
Mysis relicta Loven	–	–	–	–	–	–	+	–
Ostracoda	–	–	–	+	–	+	–	–
Insecta	+	+	+	+	+	+	+	+
Odonata	–	–	–	–	+	–	–	–
Coenagrion sp.	–	–	–	–	+	–	–	–
Plecoptera	–	–	–	–	–	–	+	+
Isogenus nubeculosa New.	–	–	–	–	–	–	–	+
Ephemeroptera								
Ephemera vulgata L.	–	–	–	–	–	–	–	+
Ephemera sp.	–	+	–	–	–	–	–	–
Ephemerella ignita (Poda)	–	+	–	+	–	–	–	–
Caenis horaria (Linné)	–	–	+	+	+	–	–	–
C. undosa Tiensuu	–	–	–	+	–	–	–	–
C. macrura Stephens.	+	–	+	–	–	–	+	–
Caenis sp.	–	–	–	–	–	+	–	–
Paraleptophlebia submarginata (Stephens.)	–	–	+	–	–	–	–	–
Paraleptophlebia sp.	–	–	–	–	–	–	–	+
Trichoptera	–	–	+	+	+	+	–	–
Oxyethira costalis (Curtis)	–	–	+	+	–	–	–	–
Ecnomus tenellus Ramb.	–	–	+	–	+	+	–	–
Polycentropus sp.	–	–	+	–	–	–	–	–
Cyrnus flavidus McLachlan	–	–	–	+	+	–	–	+
Neureclipsis bimaculata Linne	–	–	–	+	–	–	–	–
Phryganea bipunctata Retzius	–	–	–	+	–	–	–	–
Molanna palpata McLachlan	–	–	–	–	+	–	–	–
M. angustata Curtis	–	–	–	–	+	–	–	+
Molanna sp.	–	–	–	–	–	+	–	–
Lepidostoma hirtum Fabricius	–	–	+	–	–	–	–	–
Leptocerus cinereus Curtis	–	–	+	–	–	–	–	–
Triaenodes sp.	–	–	–	–	–	–	–	+
Athripsodes atterrimus Steph.	–	–	–	–	–	–	–	+
A. cinereus Curt.	–	–	–	–	–	–	–	+
Heteroptera	–	–	+	–	–	–	–	–
Coleoptera	–	+	+	–	+	–	+	–
Megaloptera	–	+	–	+	+	–	+	–
Sialis lutaria Linne	–	+	–	–	–	–	+	–

Taxa*	1	2	3	4	5	6	7	8
Sialis sp.	–	+	–	+	+	–	–	–
Diptera	+	+	+	+	+	+	+	+
Chironomidae	+	+	+	+	+	+	+	+
Tanypodinae	+	+	+	+	+	+	+	+
Procladius nigriventris Kieffer	–	–	–	+	–	–	–	–
P. ferrugineus Kieff.	–	–	–	–	–	–	–	+
Procladius sp.	+	+	+	+	+	+	+	+
Clinotanypus nervosus Meigen	–	–	–	+	–	–	–	–
Thienemannimyia sp.	–	–	–	–	–	+	+	–
Ablabesmyia monilis (Linne)	+	+	+	–	+	–	+	+
Ablabesmyia sp.	–	+	–	+	–	–	–	–
Orthocladiinae	+	+	+	+	+	+	+	+
Protanypus sp.	–	+	–	–	–	+	+	–
Syndiamesa nivosa Goetghebuer	–	–	–	–	–	–	+	–
S. orientalis Tshernovskij	–	–	–	–	–	–	+	–
Diamesa sp.	–	+	–	–	+	–	+	–
Potthastia campestris (Edwards)	–	–	–	+	–	–	–	–
Prodiamesa olivacea (Meigen)	–	+	–	–	–	–	–	–
P. bathyphila Kieffer	–	+	–	+	+	+	–	–
Trissocladius zalutschicola (Lipina)	+	+	+	–	+	–	–	–
T. paratatricus (Tshernovskij)	–	+	–	–	–	+	+	–
T. potamophilus (Tshernovskij)	–	–	+	+	–	–	+	+
T. fontinalis (Tshernovskij)	–	–	–	+	–	–	–	–
Trissocladius sp.	–	–	–	–	–	–	+	–
Heterotanytarsus apicalis Kieffer	–	+	–	–	–	+	+	–
Orthocladius saxicola Kieffer	–	–	–	–	–	–	+	+
Orthocladius sp.	–	+	+	–	+	–	+	–
Cricotopus silvestris (Fabricius)	–	–	–	–	+	–	–	–
C.algarum Kieffer	–	–	+	+	+	–	+	+
Cricotopus sp.	–	+	–	–	–	–	–	–
Paratrichocladius inaequalis Kieffer	–	–	–	–	–	–	+	–
P. triquetra (Tshernovskij)	+	+	+	+	+	+	–	–
Psectrocladius psilopterus Kieffer	–	+	+	–	+	–	+	–
P. simulans Johannsen	–	+	–	–	–	–	+	–
P. dilatatus (Van der Wulp)	–	+	–	–	–	–	–	–
P. septentrionalis Tshernovskij	–	+	–	–	+	–	–	–
Microcricotopus bicolor Edwards	–	+	–	+	+	–	–	–
Limnophyes karelicus (Tshernovskij)	–	+	–	–	–	+	+	–
Limnophyes sp.	–	–	–	–	+	–	–	–
Metriocnemus sp.	–	+	–	–	–	–	–	–
Smittia sp.	–	–	–	–	–	–	–	+
Thienemannia sp.	–	–	+	–	–	–	–	–
Chironominae	**+**	**+**	**+**	**+**	**+**	**+**	**+**	**+**
Tanitarsini	+	+	+	+	+	+	+	+
Zavrelia pentatoma Kieffer	–	+	–	–	–	–	–	–
Lauterbornia coracina Kieff.	–	–	–	+	–	–	–	+
Stempellinella minor (Edwards)	–	–	–	+	–	+	+	–
Stempellina bausei (Kieffer) Edwards	–	–	–	–	–	+	–	–
S. subglabripennis (Brundin)	–	–	–	+	–	–	–	–
Constempellina brevicosta (Edwards)	–	–	–	–	–	+	+	–
Tanytarsus usmaensis Paast	–	–	–	+	–	–	–	–
Tanytarsus sp.	+	+	+	+	+	+	+	+
Paratanytarsus sp.	–	+	+	–	+	+	+	–
Cladotanytarsus sp.	–	+	+	+	+	–	+	–
Micropsectra praecox (Meigen)	–	+	–	–	+	–	–	–
M. lobatifrons Botnariuc et Cure	–	–	–	–	–	+	–	–
Micropsectra sp.	–	+	–	+	–	+	–	–
Corynocera ambigua Zetterstedt	–	–	–	–	+	–	–	–
Chironomini	+	+	+	+	+	+	+	+
Chironomus plumosus (Linne)	–	+	–	–	–	–	–	–
Chironomus sp.	+	+	+	+	+	+	+	–
Einfeldia carbonaria (Meigen)	–	–	–	–	+	–	–	–
Cryptochironomus defectus Kieffer	–	+	+	+	+	–	+	+
C. ussouriensis Goetghebuer	–	+	–	–	–	–	–	–
C. tshernovskij Vershinin	–	–	–	–	–	–	+	–
Cryptochironomus sp.	–	+	–	–	–	–	–	–
Cryptocladopelma viridula (Fabricius)	+	+	+	+	+	+	+	–
Cryptotendipes nigronitens (Edwards)	–	–	–	–	–	+	–	–

Taxa*	1	2	3	4	5	6	7	8
Demicryptochironomus vulneratus (Zetterstedt)	–	+	+	+	+	+	+	–
Harnischia fuscimana Kieffer	–	+	–	–	–	+	–	–
H. curtilamellata (Malloch)	–	–	+	–	–	–	–	–
Harnischia sp.	–	–	–	–	–	+	–	–
Leptochironomus tener (Kieffer)	–	–	–	+	+	+	–	–
Paracladopelma camptolabis (Kieffer)	–	+	–	–	–	–	–	–
Parachironomus vitiosus (Goetghebuer)	–	–	–	+	–	–	–	–
Pseudochironomus prasinatus (Staeger)	–	+	+	+	+	–	+	+
Limnochironomus nervosus (Staeger)	–	+	+	–	+	–	+	+
L. tritomus (Kieffer)	–	+	–	+	–	–	–	+
Limnochironomus sp.	–	+	–	–	–	–	–	–
Endochironomus dispar (Meigen)	–	–	–	–	+	–	–	–
Endochironomus sp.	–	+	–	+	+	+	–	–
Glyptotendipes gripecoveni Kieffer	–	–	–	+	+	–	–	–
Sergentia coracina (Zetterstedt)	–	–	–	–	–	–	+	–
S. longiventris Kieffer	+	+	+	–	–	–	–	–
Sergentia sp.	–	–	–	–	–	–	–	+
Pentapedilum exectum Kieffer	–	+	+	+	–	–	–	–
P. sordens (Van der Wulp)	–	–	+	+	–	–	–	–
Pentapedilum sp.	–	+	–	–	–	–	–	–
Polypedilum nubeculosum (Meigen)	–	+	–	–	+	+	–	–
P. convictum (Walker)	–	–	–	–	+	–	–	–
P. bicrenatum Kieffer	–	+	+	–	+	–	–	–
P. scalaenum (Schrank)	–	+	+	+	+	+	+	–
P. abberrans Tshern.	–	–	–	–	–	–	–	+
Pagastiella orophila (Edwards)	+	+	+	–	+	+	+	–
Microtendipes pedellus (De Gree)	–	+	+	+	+	–	+	–
M. tarsalis (Walker)	–	–	–	–	+	–	–	–
Paratendipes albimanus (Meigen)	–	–	–	–	–	+	–	–
P. intermedius Tshernovskij	–	–	+	–	–	–	–	–
Paralauterborniella nigrochalteralis (Malloch)	–	–	–	–	–	+	–	–
Stictochironomus histrio (Fabricius)	–	+	–	–	–	–	–	–
S. crassiforceps (Kieffer)	+	+	+	–	+	–	+	+
Stictochironomus sp.	–	+	–	–	–	+	–	–
Chironomidae sp.	+	+	+	+	+	+	+	+
Ceratopogonidae	+	+	+	+	+	+	+	+
Simulidae	–	–	–	–	–	–	+	–
Chaoboridae	+	+	+	+	+	–	–	–
Chaoborus flavicans Meig.	–	–	–	+	–	–	–	–
Chaoborus crystallinus De Geer	–	–	+	–	–	–	–	–
Chaoborus sp.	+	+	+	–	+	–	–	–
Tabanidae	–	+	–	+	–	–	–	–
Tabanus sp.	–	+	–	+	–	–	–	–
Gastropoda	+	+	+	+	+	+	+	+
Lymnaea ovata Drap.	–	–	–	–	–	–	–	+
Planorbis sp.	–	–	–	–	–	–	–	+
Anisus laevis (Alder)	–	–	–	+	–	–	–	–
Bithynia tentaculata (Linne)	–	–	–	–	+	–	–	–
Planorbarius sp.	–	–	–	–	+	–	–	–
Valvata cristata O.F.Muller	–	+	–	–	+	–	–	–
V. pulchella Studer	–	–	–	+	–	–	–	–
V. piscinalis (O.F.Muller)	–	–	–	–	+	–	–	–
Bivalvia	+	+	+	+	+	+	+	+
Sphaerium sp.	–	+	–	–	–	–	–	–
Pisidium sp.	–	–	–	–	–	–	–	+
Neopisidium conventus (Clessin)	–	–	–	–	–	+	–	–
Euglesa lilljeborgi (Clessin)	–	–	–	+	–	+	–	–
E. henslowana (Sheppard)	–	–	–	–	–	+	–	–
E. casertana (Poli)	–	–	–	–	–	+	–	–
Euglesa sp.	–	+	–	+	–	+	–	–
Bryozoa	–	–	–	+	–	–	–	–

Note: 1 = lakes in Kalevala National Park; 2 = lakes in Kostomuksha Strict Reserve; 3 = lakes in Koitajoki National Park; 4 = Lake Monastyrskoye (Vodlozero National Park), 5 = lakes in Zaonezhye; 6 = Kizhi Skerries, Lake Onega; 7 = Lake Paanajarvi (Paanajärvi National Park); 8 = Lake Tulos (Tuulos Natural Park).

Species names given as follows: **Oligochaeta** – Chekanovskaya, 1962, **Hirudinea, Odonata and Mollusca** – 'A key to the freshwater invertebrates.., 1977', **Plecoptera** – Lillehammer, 1988, **Ephemeroptera** – Macan, 1979, **Trichoptera** – Spuris, 1989, **Chironomidae** – Pankratova, 1970, 1977, 1980.

4.4.2. The influence of natural and anthropogenic factors on the macrozoobenthic diversity of Karelian rivers

Introduction. The conservation of biological diversity is one of the main aims of environment protection programmes. It is difficult, however, to give a simple explanation of the mechanism by which biodiversity develops as numerous natural and anthropogenic factors affect the number of species present in communities (Begon et al.,1989). The effects on zoobenthos of current velocity, alimentation of the river and the content of dissolved organic matter in the water is reviewed below. The present article addresses data collected during the period 1981–1998 from fifty Karelian rivers lying in the basins of the White Sea and lakes Onega and Ladoga. The collecting and processing of samples was carried out using standard methods (Zhadin, 1956). The values of hydrochemical parameters (BOD_5, COD_{Mn}) were determined at the Laboratory of Hydrochemistry, Northern Water Institute, KRC, RAS.

Karelian rivers are usually characterised by considerable gradients (from 2–3 to 5–8 m/km). The steepest gradients are commonly observed in the lower part of rivers. In other words, rivers exhibit the socalled overturned profile (Grigoryev, 1961). Numerous rapids with high current velocity exert a powerful effect on the formation of zoobenthic communities. Rheophilic species of hydrobios sensitive to changes in conditions tend to dominate at these locations. It was for this reason that the rivers of Karelia and the Kola Peninsula were classified into separate hydrobiological types (Zhadin, 1950).

Rivers and lakes form complex fluvio-lacustrine systems. The taxonomic composition and quantitative indices of benthic communities are largely determined by the lake surface-drainage area ratio of the water body system in question. Additional quantities of mineral substances, dissolved organic matter and plankton supplied by lakes affect the development of benthic fauna. As a result, the population density and biomass of zoobenthos tend to increase in rivers with drain catchment areas dominated by lakes. Thus, for example, in three rivers of differing lake surface-drainage area ratio (Pyalma – 1.7%, Tuba – 3.5% and Lizhma – 19.4%) the population densities of macrozoobenthos in August 1971 were 9200, 11600 and 33200 individuals / m^2 , respectively (Khrennikov, 1987).

Results. There are two main environmental factors which affect the biodiversity of macrozoobenthic communities in the rivers of Karelia (Fig.57), namely, lake surface-drainage area ratio and current velocity.

Preliminary data indicates the presence of over 300 macroinvertebrate species in Karelian streams. Caddis fly fauna is the most diverse and comprises no less than 98 species. Amphibiotic insects account for over 80% of the total number of identified species (Appendix).

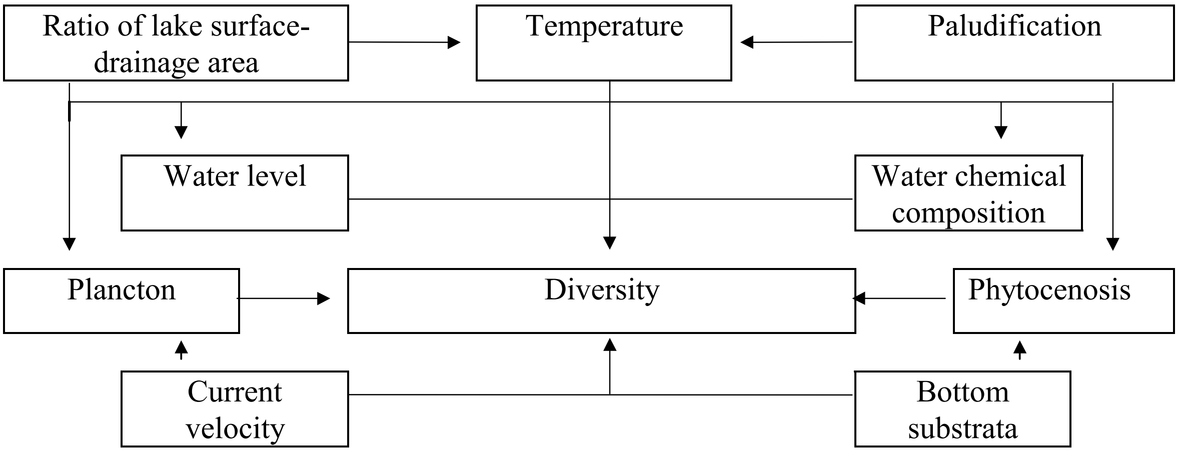

Fig. 57. The main factors responsible for the diversity of macrozoobenthic communities in Karelian rivers

It should be noted that some species, e.g. *Isogenus nubecula, Isoperla difformis* (stone flies), *Brachycercus harrisella* (mayflies), *Agabus ulidinosus* (beetles), *Glossosoma (Diploglossa) nylanderi* and *Arctopsyche ladogensis* (caddis flies) are listed in the Red Data Book of Karelia (1995). Other species such as *Aphelocheirus aestivalis* (aquatic Coleoptera) and *Habrophlebia fusca* (mayflies) are included in the Red Data Book of East Fennoscandia (1998). Another important protected species, the European freshwater pearl mussel (*Margaritifera margaritifera*), is typical of river zoobenthos. Since this species is highly sensitive to environmental pollution the rise of economic activities together with a decline in prolificacy of *Salmonidae* has led to a fall in the number of viable populations of *M. margaritifera*. One of two stable populations (containing some six million individuals) of European freshwater pearl mussel inhabits the lower part of the River Keret which discharges into the White Sea (Zyuganov et. al.,1993).

Table 40 shows the number of species of the main groups of riverbed invertebrates as a function of biotope factors reviewed above. It appears that current velocity exerts a profound influence on the numbers of oligochaete, gastropod, water bug, stone fly, black fly and other dipterous species. However, the number of species of stone fly and black fly rise with increasing current velocity. Forexample, oligochaetes occurring at locations of high current

Table 40

Proportion of species of major macrobenthic groups (% of total number in each group found in Karelia) in various types of river biotope in Karelia*

Group	Type of biotope			
	I	II	III	IV
Oligochaeta	33	89	39	83
Hirudinea	83	50	50	83
Gastropoda	40	70	35	60
Bivalvia	70	90	50	30
Odonata	50	40	30	50
Ephemeroptera	70	62	35	57
Plecoptera	89	39	39	22
Heteroptera	40	70	30	50
Coleoptera	50	50	38	50
Trichoptera	52	45	29	45
Simuliidae	70	30	73	20
Diptera var.	29	57	57	95

* Note: types of biotopes I = rivers with high degrees of lacustrine nutrition (ratio of lake surface to drainage area > 10%) in channel erosion zones (current velocity > 0.3 m/s); II = same river types in alluvium and suspension deposition zones (current velocity < 0.2 m/s); III = rivers with high degrees of mire nutrition (ratio of mire surface to drainage area > 30%) in erosion zones; IV = same river types in alluvium zones.

velocity (types I and III) account for 36% of all oligochaetes found in Karelian rivers. The corresponding figure for low current velocity (types II and IV) rivers is 86%. Thus, the species diversity of oligochaetes in the latter case increases by a factor of more than two.

As the lake surface-drainage area ratio rises and the contribution of mires to river nutrition decreases so the number of bivalve mollusc, mayfly, stone fly and caddis fly species increases while Diptera fauna becomes less diverse. Thus, for example, 70% (type I) and 90% (type II) of the total number of bivalve mollusc species known to Karelia were found in the benthos of rivers with a high degree of lacustrine type nutrition. Where catchment areas are highly paludified (types III and IV) the corresponding figure for these species drops to 40%.

To sum up, current velocity and the degree of paludification or lake surface-drainage area ratio of a river catchment area exert a marked effect on the composition and diversity of most groups of invertebrates. Organisms most sensitive to these various factors (stone flies, many mayflies, caddis flies etc.) inhabit stretches of rivers with high lake surface-drainage area ratios and high current velocities. A decline in the diversity of riverbed fauna is most commonly associated with the disappearance of these groups from biocenoses. It is for this reason that rivers possessing such characteristics should be included in the structure of protected territories.

The species diversity of communities may be quantified simply in terms of the number of species. However, there are other indices which may be used to assess species diversity, such as evenness (J) (Begon et al.,1989; Alimov,1989; Ivanova,1997). The following equation was used in order to estimate this index quantitatively:

$$J = H / \log_2 S,$$

where Í is Shannon’s diversity index and S is the number of species in a community.

A low level of diversity of river benthocenoses is typically caused by organic pollution from municipal and agriculture sources. Heavy pollution results in the complete degradation of river fauna or its impoverishment to a few most tolerant species. The intensity of organic pollution is indirectly indicated by the BOD$_5$ value. Figure 58 shows the relation of species richness and evenness to this index. As has already been mentioned, the true effect of a given factor on the characteristics of a community is shown diagrammatically by a curve which delineates the resultant distribution. The position of points lying below the curve is affected by other factors (Shirokov,1982; Ivanova, 1997; Ivanova, 1987).

As the amount of organic matter increases the number of species in zoobenthic communities gradually decreases. At the same time, the degree of evenness remains high up to BOD$_5$ values of 4 mg Î/l. At higher BOD$_5$ valuesboth of these indices fall. A BOD$_5$ value of approximately 4 mg O_2/l may be considered to be critical. If this value is exceeded the structure of communities becomes simpler, biodiversity declines and only tolerant organisms thrive.

Another important cause of degradation of riverbed fauna communities in Karelian rivers is the build up of substances of humic origin. In such cases contamination results from the drainage of wetlands and paludified areas and causes changes in the natural hydrochemical characteristics of rivers. Although such drainage is not disastrous for water ecosystems it can have a very significant effect if conducted on a large scale. Figure 59 shows the relationship between the diversity pattern of benthic communities and chemical oxygen demand (COD$_{Mn}$) which indirectly indicates the amount of humic substances present in water.

As the effect of drainage runoff increases, the number of invertebrate species present in communities falls, the evenness remains high enough to reach a COD$_{Mn}$ value of approximately 40 mg O/l. The high critical value of this hydrochemical parameter seems to show that river zoobenthocenoses can adapt to the presence of large quantities of humic substances in the natural water bodies of the region. However, if COD$_{Mn}$ values continue to rise above this level the evenness declines because the resistant species such as oligochaete, *Diptera*, *Odonata* and *Coleoptera* start to dominate.

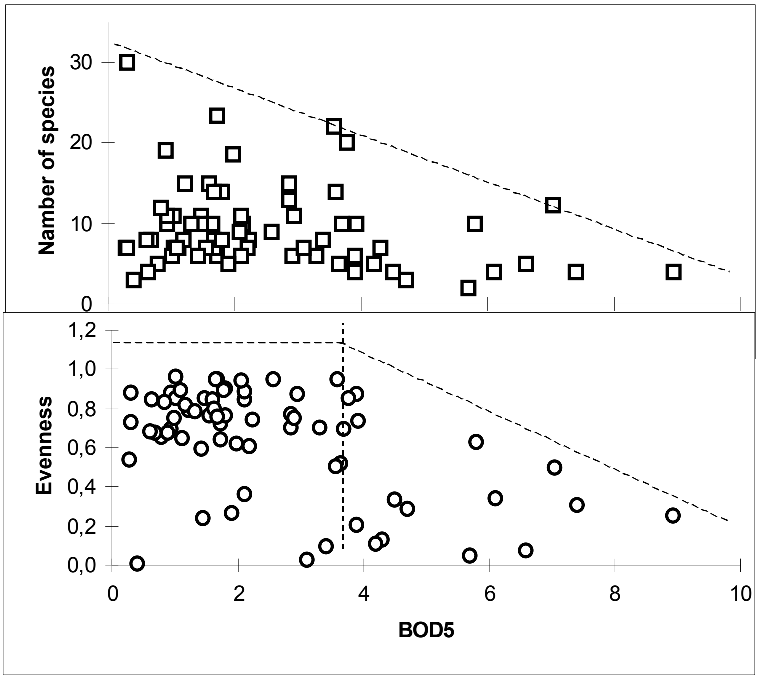

Fig. 58. Relation of the diversity indices of macrozoobenthic communities in Karelian rivers to BOD_5 values, mg O/l

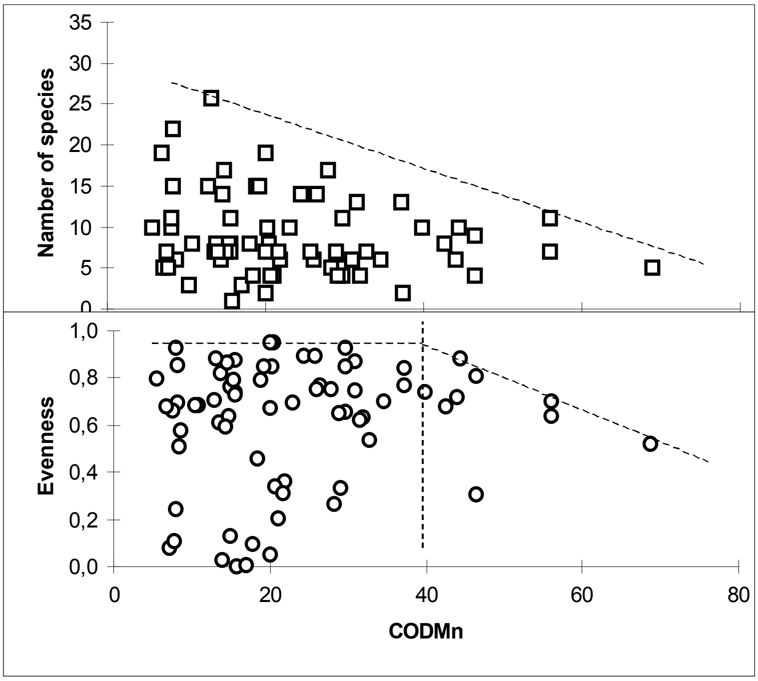

Fig. 59. Relationship between the diversity indices of macrozoobenthic communities in Karelian rivers and chemical oxygen demand (COD_{Mn}) values, mg O/l)

Conclusion. To sum up, the high biological diversity of riverbed fauna of Karelian rivers is favoured by various characteristics of the region's hydrographic network. These include the numerous stretches of rivers with rapid currents and the high lake surface-drainage area ratio of river catchment areas. The fauna which develop in these biotopes consist mainly of rheophilic, oxygen-requiring invertebrate species sensitive to adverse anthropological effects. The main factor responsible for decreasing faunistic diversity in riverbed cenoses is the raised concentration of organic matter in the water. The more marked this effect, the greater the reduction in the number of species. Average critical contamination values may be estimated in terms of the variation pattern of evenness. Excessively high values result in the degradation of zoobenthic communities.

Appendix

Taxonomic composition of river macrozoobenthos in Karelia

TURBELLARIA
Planaria torva M.Sch.**
Planaria sp.
NEMATODA
OLIGOCHAETA
Stylaria lacustris (L.)*
Ripistes parasita (Schmidt)*
Slavina appendiculata (Vdekem)**
Dero digitata Ferron.**
D. dorsalis (Mull.)**
Nais behningi Mich.**
N.communis Pig.**
N.alpina Sper.*
Pristina foreli Pig.**
Aulodrilus limnobius Bret.**
Limnodrilus udekemianus Clap.**
L. hoffmeisteri Clap.**
L. helveticus Pig.**
Tubifex tubifex (Mull.)**
Peloscolex ferox (Eisen)**
Lumbriculus variegatus (Mull.)**
Stylodrilus heringianus Clap.**
Eiseniella tetraedra f.typica,(Savigny)**
HIRUDINEA
Hemiclepsis marginata (O.F.Mull.)
Glossiphonia complanata (L.)
G. heteroclita (L.)
Helobdella stagnalis (L.)
Erpobdella octoculata (L.)
E. lineata (0.F.Mull.)
ISOPODA
Asellus aquaticus L.
GASTROPODA
Lymnaea stagnalis (L.)
L. Auricularia (L.)
L. lagotis (Schrank)*
L. ovata (Drap.)
L. palustris (Mull.)
L. truncatula (Mull.)**
L. glutinosa (Mull.)*
Physa fontinalis (L.)
Planorbis planorbis (L.)*
Planorbarius corneus (L.)
Anisus vortex (L.)
A. contortus (L.)
A. acronicus (Ferus.)
Choanomphalus rossmaessleri (A.Schmidt)
Ancylus fluviatilus Mull.
Valvata pulchella Stud.
V. cristata Mull.
Viviparus viviparus (L.)
V. contectus (Millet)*
Bithynia tentaculata (L.)
BIVALVIA
Margaritifera margaritifera L.*
Unio pictorum (L.)
Sphaerium corneum (L.)
S. nitidum (Cl.in West.)
Sphaerium sp.
Pisidium amnicum (Mull.)
Euglesa casertana (Poli)
E. Lilljeborgi (Cles.)
E. pulchella (Jen.)
PLECOPTERA
Taeniopteryx nebulosa (L.)
Amphinemura borealis (Mort.)
A. standfussi (Ris.)*
Nemoura cinerea (Retz.)
N. flexuosa Aub.
Nemoura sp.
Leuctra digitata Kemp.
L. fusca (L.)
Capnia atra Mort.
Perlodes dispar (Ramb.)
Diura bicaudata (L.)
D. nanseni (Kemp .) *
Isogenus nubecula Newm.
Isoperla difformis (Klap.)
I. grammatica (Poda)
I. obscura (Zett.)
Xanthoperla apicalis (New.)
Siphonoperla burmeisteri Pict.
HEMIPTERA
Notonecta glauca L.
Aphelocheirus aestivalis (Fabr.)
Ilyocoris cimicoides (L.)*
Nepa cinerea L.
Micronecta sp.
Corixa sp.
Sigara praeusta (Fieb.)
S. striata (L.)
S. wollastoni (Doug.)
S. falleni (Fieb.)
Sigara sp.
ODONATA
Agrion splendens (Har.)
A. puella L.**
A. virgo (L.)
Coenagrion armatum (Charp.)
C. hastulatum (Charp.)
Gomphus vulgatissimus (L.)
Aeshna sp.
Somatochlora metallica (vanderLind.)
EPHEMEROPTERA
Ephemera vulgata L.
Potamanthus luteus (L.)
Heptagenia sulphurea (Mull.)
H. fuscogrisea (Retz.)
Siphlonurus lacustris Eat.
S.aestivalis (Eat.)
Baetis vernus Curt.
B. rhodani (Pict.)
B. pumilus Burm.**
B. scambus Eat.**
Baetis niger (L.)
B. digitatus Beng.
Baetis sp.
Cloeon dipterum (L.)
Procloeon ornatum Tschern.
Ephemerella ignita (Poda)
Caenis undosa Tiens.
C. horaria (L.)
C. moesta Bengt.*
Brachycercus harrisellus (Curt.)
Leptophlebia marginata (L.)
Paraleptophlebia cincta (Retz.)
P. submarginata (Steph.)
Habrophlebia fusca (Curt.)

COLEOPTERA
Haliplus lineolatus Mannh.*
Haliplus sp.
Coelambus sp.
Hydroporus striola Gyll.*
H. tristis Payk.*
H. tartaricus Lec.*
Potamonectes sp.
Ilybius sp.
Porhydrus lineatus F.*
Platambus maculatus L.*
Agabus uliginosus L.*
A. sturmi Gill.*
Agabus sp.
Rhantus sp.
Colymbetes striatus L.
Colymbetes sp.
Gyrinus marinus Gyll.*
Ochthebius pusillus Steph.
O. evanescens J.Sahlb.*
Helophorus nanus Sturm.*
Anacaena limbata F.*
Laccombus sp.
Philhydrus marinellus F.*
Cercyon litoralis Gyll.*
Elmis sp.
Normardia nitens Muell.*
Limnius volckmari Panz.
Donacia aquatica L.*
Galerucella sp.
TRICHOPTERA
Rhyacophila nubila Zett.
R. fasciata Hag.*
R. pascoei McL.**
R. dorsalis Curt.**
Diploglossa nylanderi McL.*
Agapetus ochripes Curt.
Eomystra altaica Mart.**
Agraylea multipunctata Curt.
Ithytrichia lamellaris Eat.
Hydroptila tineoides Dalm.
H. cornuta Mos.*
H. sparsa Curt.
H. forcipata Eat.**
Oxyethira flavicornis Pict.
O. distinctella McL.*
O. tristella Klap.*
O. frici Klap.*
Tricholeiochiton fagesii Guin.*
Philopotamus montanus Donov.*
Wormaldia subnigra McL.
Psychomyia pusilla Fabr.
Lype phaeopa Steph.
Tinodes sp.
Polycentropus flavomaculatus Pict.
P. irroratus Curt.**
Holocentropus dubius Ramb.
Holocentropus sp.
Cyrnus flavidus McL.
C. trimaculatus Curt.*
Neureclipsis bimaculata L.
Arctopsyche ladogensis Kol.
Hydropsyche pellucidula Curt.
H. angustipennis Curt.
H.ornatula McL.
H. guttata Pict.*
H. instabilis Curt.**
H. silfvenii Ulm.
H. nevae Kol.*
Chematopsyche lepida Pict.
Phryganea bipunctata Retz.
Agrypnia obsoleta Hag.**
A. pagetana Curt.*
Oligostomis reticulata L.
Mollana angustata Curt.
M. Albicans Zett.*
Molannodes tincta Zett.*
Sericostoma personatum Kirb.et Sp.
Notidobia ciliaris L.*
Goera pilosa Fabr.*
Silo pallipes Fabr.
Brachycentrus subnubilus Curt.
Micrasema setiferum Pict.
M. gelidum McL.*
Lepidostoma hirtum Fabr.
Athripsodes cinereus Curt.
Ath. atterimus Steph.*
Ath. commutataus Rost.*
Ceraclea fulva Ramb.**
C. annulicornis Steph.**
C. nigronervosa Retz.*
C. annulicornis Steph.
C. senilis Burm.*
C. perplexus McL.*
C. excisa Mort.*
Mystacides azurea L.
M. nigra L.*
M. longicornis L.*
Triaenodes bicolor Curt.
T. reuteri McL.**
Oecetis furva Ramb.
O. ochracea Curt.*
Apatania wallengreni McL.*
Nemotaulius punctatolineatus Retz.
Glyphotaelius pellucidus Retz.
Anabolia soror McL.
A.concentrica Zett.*
Potamophylax latipennis Curt.
Rhadicoleptus alpestris Kol.*
Halesus radiatus Curt.
H. tessellatus Ramb.
Chaetopteryx villosa Fabr.
C. sahlbergi McL.*
Limnephilus borealis Zett.
L. femoratus Zett.*
L. fuscinervis Zett.*
L. rhombicus L.
L. politus McL.
L. nigriceps Zett.
L. extricatus McL.*
L. sericeus Say*
L. griseus L.*
L. fenestratus Zett.*
L. pantodapus McL.*
Arctopora trimaculata Zett.
Grammotaulus nigropunctatus Retz.*
G. sibiricus McL.*
Ironoquia dubia Steph.
Micropterna sp.
MEGALOPTERA
Sialis sp.
DIPTERA
SIMULIIDAE
Prosimulium hirtipes (Fries.)
Stegopterna richteri End.*
Cnephia lapponica (End.)

*C. trigonia (Lundstr.)**
Eusimulium dogieli (Uss.)
*E. annulum (Lundstr.)**
*E. olonicum (Uss.)**
*E. crassum (Rubz.)**
E. latipes (Mg.)
E. bicorne (Dor. et Rubz.)
E. beltukovae Rubz.
E. pygmaeum (Zett.)
*E. amgustitarse (Lundstr.)**
E. aureum (Fries.)
*E. latizonum Rubz.**
Schonbaueria pusilla (Fries.)
*S. subpusilla (Rubz.)**
Wilhelmia equina (L.)
*Byssodon transiens End.**
*Boophthora erythrocephala (DeGeer)**
*Gnus relictum (Rubz.)**
Odagmia ornata (Mg.)
O. frigida (Rubz.)
Simulium tuberosum (Lundstr.)
*S. nolleri Fried.**
S. morsitans Edw.
S. paramorsitans Rubz.
S. truncatum Lundstr.
*S. austeni Edw.**
S. argyreatum Mg.
*S. reptans (L.)**
*CHIRONOMIDAE***
Zavrelia sp. Kieff.
Micropsectra gr. praecox Mg.
Tanytarsus sp.
Demicryptochironomus vulneratus Zett.
Cryptochironomus pararostratus Lenz.
Polypedilum scalaenus Schr.
P. convictum Walk.
Microtendipes pedellus Mg.
Psectrocladius psilopterus Kieff.
P. septentrionalis Tshernovskij, sp.n.
Cricotopus silvestris F.
C. latidentatus Tshernovskij, sp.n.
C. algarum Kieff.
Synorthocladius semivirens Edv.
Eukiefferiella longicalcar Kieff.
Eu. bicolor Zett.
Limnophyes karelicus Tshernovskij
Corynoneura sp.
Thienemanniella flaviforceps Kieff.
Thienemanniella sp.
Ablabesmyia. monilis L.
Zavrelimyia sp.
Conchapelopia sp.
Procladius sp.
LIMONIIDAE
Eriocera sp.
*Helobia sp.***
Dicranota sp.
TIPULIDAE
STRATIOMYDAE
CULICIDAE
SYRPHIDAE
TABANIDAE
CERATOPOGONIDAE
Culicoides sp.
Bezzia sp.

Note: an asterisk is used to mark the species included in the list on the basis of data obtained by various authors according to: Lake fauna… (1965); two asterisks are used for the species identified by V.V. Khrennikov (Khrennikov,1978,1995) in Karelian rivers; the names of species are given according to: Oligochaeta, Hirudinea, Bivalvia, Gastropoda, Heteroptera, Odonata – (A key to the.., 1977), Plecoptera – (Lillehammer, 1988), Ephemeroptera – (Aquatic Insects of.., 1996), Trichoptera – (Spuris, 1989), Simuliidae – (Usova, 1961), Chironomidae – (Pankratova, 1970, 1977, 1983).

4.5. Fish

4.5.1. Structural variations in the fish communities of some lakes in Fennoscandia

Introduction. The impact of human activities has grown considerably during the past decade and there are all signs that this trend will continue. Therefore, it is important to study and preserve the biodiversity of all valuable localities as well as animal and plant populations. Since threatened species cannot be protected without protecting entire ecosystems so undisturbed water bodies and lakes located in strict reserves have become the focus of conservation efforts. Their zonal and regional characteristics need to be thoroughly studied so as to provide a theoretical and ecological basis for the conservation of biodiversity.

The aim of our study was to examine the fish populations of certain undisturbed lakes in Finnish Lapland and Russian Karelia.

Four lakes in North Finnish Lapland and six lakes in western Russian Karelia were studied. The lakes are unspoilt because their catchment areas are sparcely populated, there are no large industrial plants or fish hatcheries nearby and only recreational fishing is permitted.

Characteristics of the lakes. The lakes studied in North Lapland were Pulmankijärvi (70°00’ N, 28°00’ E), Mantojärvi, Saarijärvi and Kevojärvi, (69°30’ N, 27°00’ E). They are all located in the Holarctic zone (Fig. 60), the circumpolar subzone, the ice-sea province, the European district, the Barents Sea basin and the forest-tundra zone (Berg, 1949).

These lakes formed in steep-walled tectonic cracks shortly after the glacial retreat. Their altitudes above sea level varies from 17 metres (Lake Pulmankijärvi) to 75 metres (Lake Kevojärvi). They are small in area, i.e. between 1.0 and 11.2 km^2 (Table 41) and are morphologically similar to each other with embayed shorelines. Their bottom morphology is complex, with 35 to 96 metre deep depressions alternating with sandy and rocky shallow-water zones. Islands are not numerous.

Lying on the Finnish-Norwegian border, Lake Pulmankijärvi (area 11.2 km^2) is long and narrow in shape. It has a straight shoreline and contains no islands. All the lakes have runoff and form lake-river systems which are connected with the sea.

The water of lakes located in the subarctic region is generally unpolluted, slightly humic, very clear and fairly neutral in terms of pH (Table 41).

Primary production in northern water bodies is limited by the short vegetative period, low levels of biogenic salts and cold temperatures. The average biomass of phytoplankton in the lakes studied was 0.18 g/m^3, while the biomass of zooplankton varied from 0.1 to 0.35 g/m^3 and that of benthos from 0.4 to 3.3 g/m^3 (Table 41).

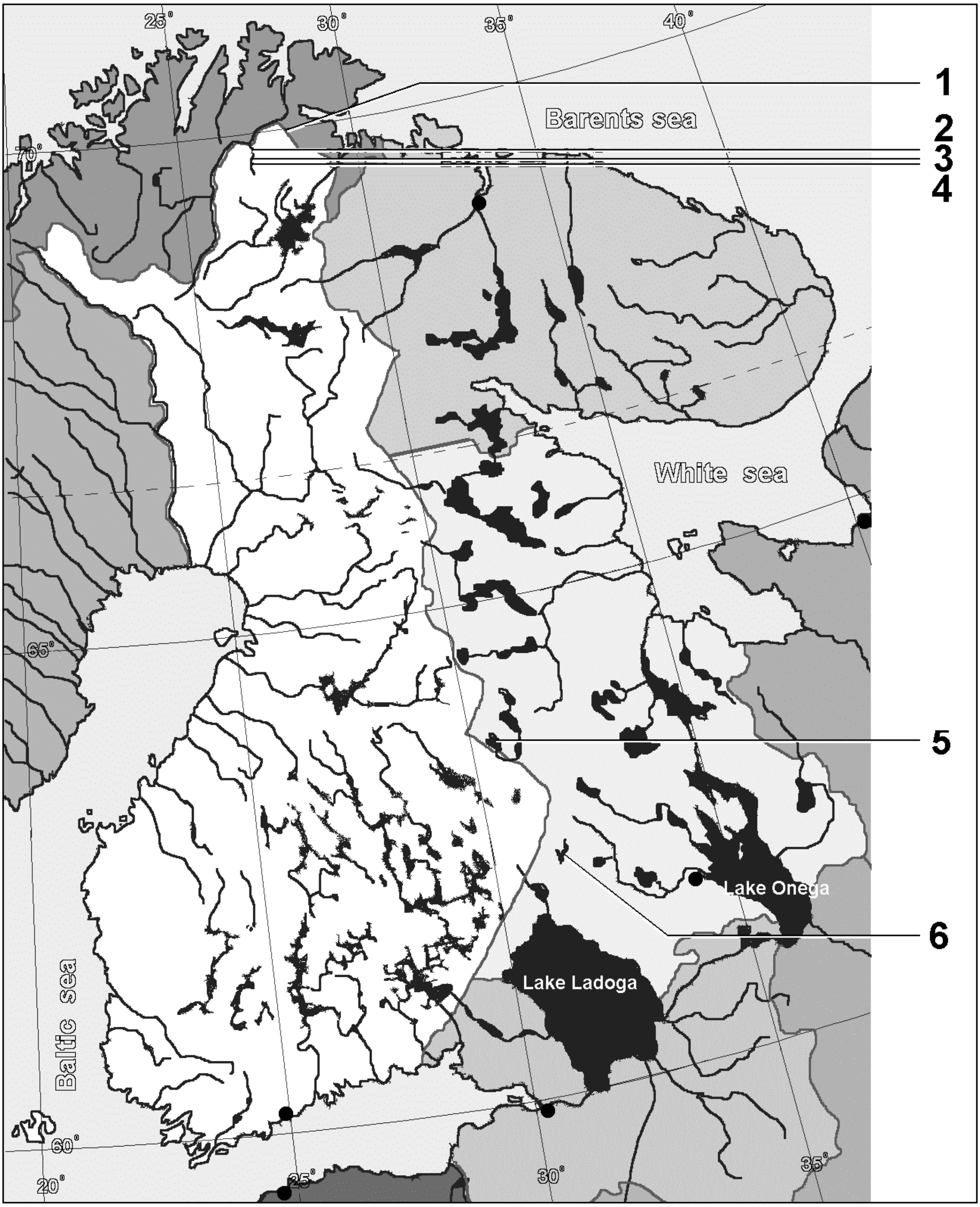

Fig. 60. Location of the water bodies studied

1. Lake Pulmankijärvi, 2. Lake Mantojärvi, 3. Lake Saarijärvi, 4. Lake Kevojärvi, 5. Lake Tuulos, 6. Tolvajärvi group of lakes

Table 41

Limnological indices of the lakes studied*

Indices	Pulmankijärvi	Kevojärvi	Mantojärvi	Tolvajärvi	Tuulos
Altitude above sea level, m	17	75	74	174	157
Catchment area, km^2	800	900	1008	47.6	858.4
Lake area, km^2	11.2	1.0	1.6	7.5	109.2
Average depth, m	11	12	19	3.5	13
Maximum depth, m	34	35	56	10	40
Specific catchment	71	900	630	6.3	7.9
Nominal water exchange	2.7	30.8	13.6	0.6	0.2
Transparency, m	3.3	4.5	6.0	2.5	3.0
Mineralisation, mg/l	28	21	27	11	10
pH	7.2	6.9	6.9	6.3	6.4
O_2 content, mg/l	10.9	9.8	–	9.6	9.8
Permanganate oxid., mg O_2/l	–	–	–	5.8	8.8
Total N, mg/l	0.21	0.20	–	0.41	0.24
Total P, mg/l	0.007	0.007	–	0.011	0.008
MEI	2.5	1.8	1.4	3.1	0.8
Biomass of phytoplankton, g/m^3 (wet weight)	0.18	–	–	0.23	0.46
Primary production, gC/m^2 /day	0.03	–	–	0.04	0.09
Biomass of zooplankton, g/m^3 (wet weight)	0.15	0.35	0.1	1.68	0.06
Biomass of zoobenthos, g/m^2 (wet weight)	0.4	3.32	2.6	2.35	0.4
Number of fish species	9	8	7	10	14

* Based on data: Natural and economic conditions ..., 1915; Grigoryev & Gritsevskaya, 1959; Pavlolvsky, 1998; Vlasova. et al., 1999; Petäjä, 1964; Eloranta, 1986; Niemelä, Vilhunen, 1987; Ryabinkin et al., 1995; author's data.

On the basis of their average phosphorus (0.007 mg/l) and nitrogen (0,.210 mg/l) contents the lakes may be classified as oligotrophic or α-oligotrophic (Kitaev, 1984).

Lakes Tolvajärvi, Ala-Tolvajärvi, Yla-Tolvajärvi, Saarijärvi and Jurikkajärvi (62°16’ N., 31°00’ E) are located in the Tolvajärvi Landscape Reserve, western Karelia. Lake Tuulos (63°03’ N, 30°08’ E) is situated in planned Tuulos Natural Park on the Russian-Finnish border (Fig. 60). The lakes belong to the Mediterranean subzone, the Baltic province, the Neva district, the Baltic Sea basin and the taiga zone (Berg, 1949).

These water bodies form a lake-river system lying at an altitude of 174 metres above sea level (Table 41). All the Tolvajärvi lakes studied are relatively small, their areas varying from 2.08 km^2 (Lake Jurikkajärvi) to 12.7 km^2 (Lake Ala-Tolvajärvi). Their shorelines are slightly embayed but bays of deep water are not present. Mud and sand cover 60% of the bottom while a further 30% consists of ferruginous mud made up of ore-bearing sand and an oolitic type of ore.

Lake Tuulos is morphologically distinct from the others. This medium-sized water body lies at an altitude of 157 metres above sea level and has a well-developed shoreline with many bays and islands (141). It covers an area of 109 km^2, has a maximum depth of 40 metres and an average depth of 13 metres.

The waters of these lakes are poorly mineralised (10–11 mg/l) and exhibit a slightly acid reaction (pH 6.2–6.6). Phytoplankton biomass varies between 0.23 and 0.46 g/m^3, that of zooplankton (predominantly copepodes) between 0.6 and 1.68 g/m^3, and that of benthos (predominantly chironimids) between 0.40 and 2.35 g/m^2 (Vlasova et al., 1998., Pavlovsky, 1998; Chekryzheva, 1998; Ryabinkin et al., 1995). The poor productivity of the lakes is a result of the very low levels of biogenic elements present. The lakes of the Tolvajärvi group are α-mesotrophic while Lake Tuulos is oligotrophic (Kitaev, 1984).

Fish populations of the lakes. Fish samples were collected with gillnets (mesh size 10 – 60 mm). Nets were mounted overnight along the shore in the littoral zone and also in the profundal zone. Total mass and numbers of fish caught were recorded according to species. The data collected was processed according to generally accepted methods (Chugunova, 1959; Pravdin, 1966; Reshetnikov, 1980). The parameters measured were fish body mass, body length (total length: AB, standard length: AD, forked length: AC), sex and gonad maturation stage. Gillrakers were counted in all whitefish caught. The age of fish was determined from the scales. Fish were classified in terms of faunistic complexes according to Nikolsky (1980).

The lake fish fauna of North Lapland are poor in terms of species diversity with only twelve species encountered. The number of species present in each lake studied varied from seven to nine (Table 42).

Fish inhabiting Arctic freshwater lakes such as whitefish, char and burbot made up 72.5% of biomass in our catches, various forms of the whitefish *Coregonus lavaretus* predominating. Fish associated with boreal submontane lakes, e.g. salmon, sea trout, grayling, minnow and sculpin, are less common (25.5%) while those of boreal plain lakes, i.e. pike and perch, account for only 1.5%. Arctic marine fish (three and nine-spiked stickleback) and boreal Atlantic fish (flounder) contribute just 0.5% (Fig.61). Fish of the *Coregonidae* family typically dominate in all Holarctic lakes.

Eleven fish species belonging to seven families were found in the lakes of the Tolvajärvi Reserve and fourteen species from eight families in Lake Tuulos. Perch, roach, whitefish and cisco were the most prolific. Pike, dace and ruffe were less common while grayling, bleak and sculpin were scarce (Table 42).

Table 42

Fish species composition in the lakes studied

Family / species	Tolvajärvi	Yla-Tolvajärvi	Ala- Tolvajärvi	Sarijärvi	Yrikkajärvi	Tuulos	Pulmankijärvi	Mantojärvi	Kevojärvi	Sarijärvi
	1966* and 1993	1993–1995				1915** and 1997	1993–1994	1993–1995	1993–1995	1993–1995
Family *Salmonidae*										
Salmo salar L. – Atlantic salmon	–	–	–	–	–	+	+	+	+	+
Salmo trutta L. – sea trout	–	–	–	–	–	–	+	+	+	+
Salvelinus alpinus (L.) – Arctic char	–	–	–	–	–	–	+	+	+	+
Family *Coregonidae*										
Coregonus albula (L.) – European cisco	+	+	+	+	+	+	–	–	–	–
Coregonus lavaretus (L.) – whitefish	–	–	–	–	–	+	+	+	+	+
Family *Thymallidae*										
Thymallus thymallus (L.) – European grayling	–	–	–	–	–	+	+	+	+	+
Family *Esocidae*										
Esox lucius L. – pike	+	+	+	+	+	+	+	–	–	–
Family *Cyprinidae*										
Abramis brama (L.) – bream	+	+	–	–	+	+	–	–	–	–
Alburnus alburnus (L.) – bleak	+	–	–	+	+	+	–	–	–	–
Leuciscus idus (L.) – ide	+	+	–	+	–	+	–	–	–	–
Leuciscus leuciscus (L.) – common dace	–	–	–	+	–	+	–	–	–	–
Phoxinus phoxinus (L.) – common minnow	–	–	–	–	–	–	–	+	–	–
Rutilus rutilus (L.) – roach	+	+	+	+	+	+	–	–	–	–
Family *Lotidae*										
Lota lota (L.) – burbot	+	+	–	–	+	+	+	–	–	–
Family *Gasterosteidae*										
Pungitius pungitius (L.) – nine-spiked stickleback	–	–	–	–	–	–	–	+	+	+
Family *Percidae*										
Gymnocephalus cernuus *(L.) – ruffe*	+	–	–	–	–	+	–	–	–	–
Perca fluviatilis L. – perch	+	+	+	+	+	+	+	–	+	–
Family *Cottidae*										
Cottus gobio L. – common sculpin	+	+	–	+	–	+	–	–	–	–
Cottus poecilopus L. – spotted sculpin	–	–	–	–	–	–	–	+	+	+
Family *Pleuronectidae*										
Platichtys flesus (L.) – flounder	–	–	–	–	–	–	+	–	–	–

* After G.M. Nosatova and G.M. Shevtsova (1966)
** Data from the book «Natural and economic conditions…» (1915).

All the fish caught belonged to four faunistic complexes (Fig. 61). Unlike in Lapland where water bodies are dominated by Arctic freshwater fish, these lakes are inhabited by boreal plain fish (56-64 %) and Arctic freshwater species (32–60%).

During analysis of fish populations special attention was paid to the biology of whitefish as this species may be used as an indicator of the natural condition of northern ecosystems (Reshetnikov, 1980; Moiseyenko, 1982, 1997; Kashulin et al., 1999).

Ecology of whitefish populations. Several forms of whitefish were found in the lakes studied. The number of gill rakers has long been used as a way of distinguishing between species and intraspecific forms because this is a genetically controlled characteristic. The various schemes devised by authors to subdivide whitefish have been described in detail by Himberg (Himberg, 1970). By the early 1940s over 100 intraspecific forms had been described (Berg,1948; Pravdin, 1954) although more recently the number of subspecies was reduced to sixteen (Shaposhnikova, 1976) and then again to six (Reshetnikov, 1980).

In Lapland three lake forms of whitefish are known. As they differ primarily in the number of gill rakers we may divide them up into groups, i.e. I. whitefish with 18–23 rakers, II. those with 24–34 rakers and III. those with 35–43 rakers. (Fig. 62; Table 43). All three forms of whitefish occur in lakes Mantojärvi and Kevojärvi while only two

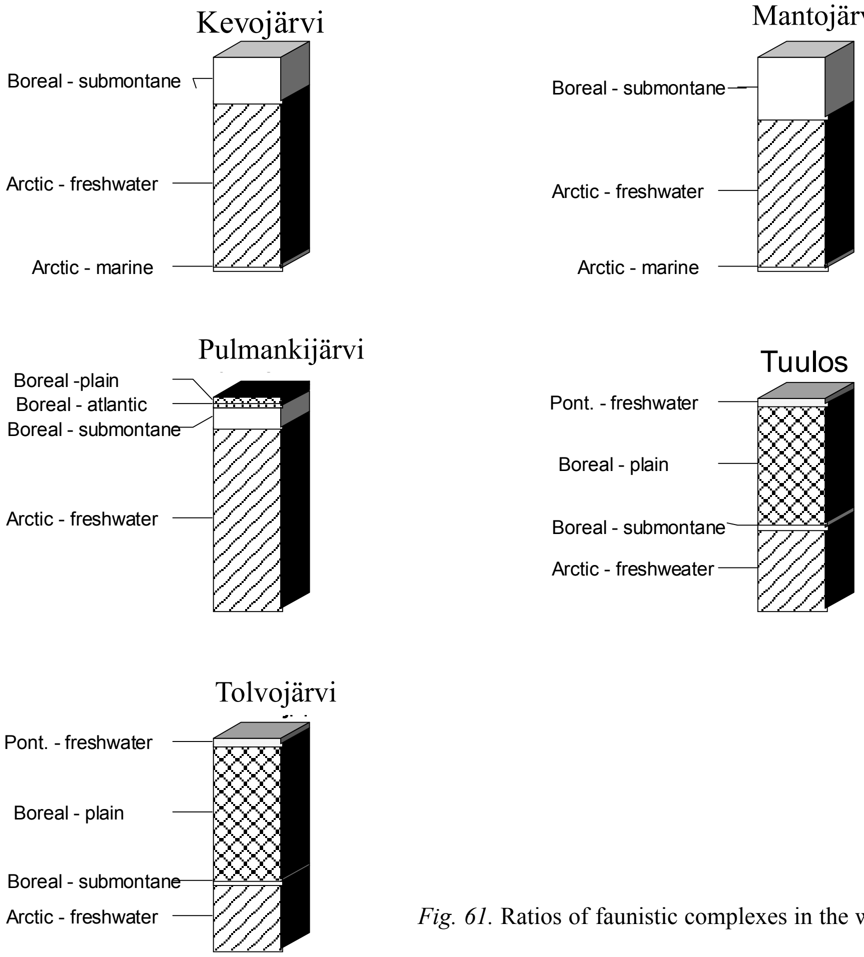

Fig. 61. Ratios of faunistic complexes in the water bodies studied

forms are found in lakes Saarijärvi and Pulmankijärvi. In lakes Mantojärvi, Saarijärvi and Kevojärvi whitefish with 24 to 34 gill rakers (average 28) made up over 90% of catches while the proportion with 19 to 23 rakers did not exceed 4% and those with 36–37 rakers only 2%. In Lake Pulmankijärvi, catches were dominated (up to 93%) by whitefish with 20 to 30 rakers (average 25) while those with 33 to 46 rakers did not exceed 7%. A small proportion of whitefish in these lakes consisted of a lacustrine-fluvial Ob form (pizhyan) with 18–22 rakers which feeds and grows in lakes and spawns in rivers. It seems that these form independent populations (Ilmast & Sterligova, 1998; Sterligova, Ilmast et al., 1998).

The bulk of our experimental catches consisted of whitefish with 24–34 gill rakers. These fed on both benthos and zooplankton, had a maximum length of 25–28 cm, a maximum mass of 150–240 g and life span of 10–13 years (Table 43).

In Finnish water bodies whitefish reaching maturity displayed relatively low length and weight indices (11.7–12.3 cm and 13.0–16.0 g) and low absolute and relative fecundity (AF = 245–275 eggs and RF = 17–20 eggs). We failed to find mention of European whitefish with such low levels of fecundity in either Russian or foreign literature. The earliest maturation of whitefish in European Russia so far reported was from Lake Kuetsijärvi in Murmansk Oblast for fish aged 1+ years with body length 6–9 cm and absolute fecundity of 600–800 eggs (Kashulin, 1994; Kashulin et al., 1999). The authors attribute the early maturation of whitefish in the Kola Peninsula to the heavy industrial pollution of its water bodies.

Table 43

Basic parameters of three forms of whitefish in the lakes studied in Lapland

Indices	Form I	Form II	Form III
Number of gill rakers	19–23	24–34	35–43
Maximum length, cm	30–44	25–28	19–24
Maximum mass, g	220–1310	150–240	70–90
Maximum age, years	11+ – 13+	7+ – 12+	6+ – 7+
Age at maturation, yrs	4+	3+	(2+) 3+
Skips annual spawning	Often	Seldom	?
Feeding	Benthos	Plankton for young fish and benthos for adults	Zooplankton

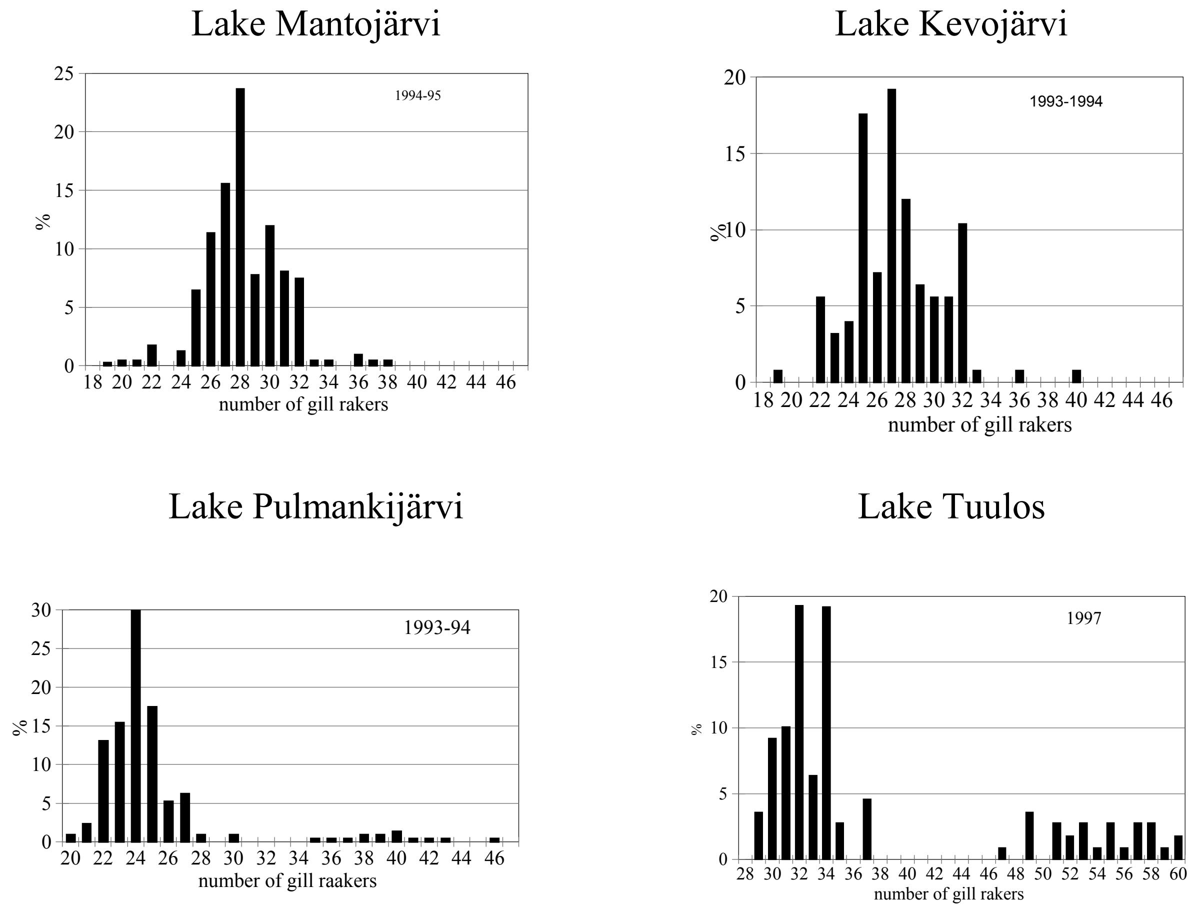

Fig.62. Number of the gill rakers of whitefish in the lakes studied

Table 44

Linear and weight growth of cisco in the lakes studied
(* large form of cisco)

Water body	Age					N	Source
	0+	1+	2+	3+	4+		
			Length (ac), cm				
Lake Onega	–	11.0	12.7	13.9	14.8	–	Gulyaeva et al., 1983
Tuulos	–	8.4	11.3	12.0	13.8	14	Sterligova et al., 1998
*Tolvajärvi	14.2	16.7	17.6	18.3	19.8	25	Pervozvansky et al., 1998
*Ala-Tolvajärvi	14.0	17.8	18.7	20.1	21.2	59	Ibid.
*Ylä-Tolvajärvi	13.5	17.5	19.0	20.5	21.0	201	Ibid.
*Saarijärvi	–	–	18.7	20.4	–	17	Ibid.
			Mass, g				
Lake Onega	–	9	18	21	26	–	Gulyaeva et al., 1983
Tuulos	–	6	14	17	22	14	Sterligova et al., 1998
*Tolvajärvi	22	44	52	66	84	25	Pervozvansky et al., 1998
*Ala-Tolvajärvi	26	57	78	94	128	59	Ibid.
*Ylä-Tolvajärvi	25	55	80	97	107	201	Ibid.
*Saarijärvi	–	–	76	107	–	17	Ibid.

Fish of the *Coregonidae* family are represented in the Tolvajärvi group of lakes solely by a large form of cisco and in Lake Tuulos by a small form of cisco and two forms of whitefish (Pervozvansky et al., 1998).

The cisco *Coregonus albula* is known to inhabit over 1000 lakes scattered over its distribution area. In Karelia, European cisco has been found in 332 out of 800 water bodies while only 60 lakes are populated by the large form of cisco (Gerd, 1949; Potapova, 1978). These two forms differ greatly in their quantitative indices (Table 44).

Lake Tuulos is inhabited by two forms of the whitefish *Coregonus lavaretus*: a medium-rakered form with 29–37 rakers (average 34) and a densely-rakered form with 47–60 rakers (average 54) (Fig. 62). These differ considerably in length, weight, maturation age and level of fecundity (Sterligova et al., 1998).

Densely-rakered whitefish made up 80% of catches. Mature specimens varied in length from 12 to 22 cm, weighed between 6 and 120 g and were aged 1+ to 5+ years. Most fish reached maturity at the age of 2+ years although a few achieved it a year earlier. The smallest sexually mature female whitefish was 1+ year in age, 13.5 cm long, had a mass of 25 g, an absolute fecundity of 995 eggs and a relative fecundity of 40 eggs. The largest female was 4+ years old and had an absolute fecundity of 2760 eggs and a relative fecundity of 31 eggs.

Multi-rakered whitefish in our catches were larger. They varied in length from 18 to 39 cm, in weight from 100 to 780 g and in age from 2+ to 8+ years. Males reached maturity at the age of 5+ or 6+ years and females at 7+ or 8+ years. The absolute fecundity of one particular female exemplar aged 7+ years was 16 040 eggs and relative fecundity was 27 eggs. The corresponding figures for an 8+ year old female were 17600 and 24 eggs, respectively.

Discussion. The fish populations of unspoilt water bodies in Finnish Lapland contain only a few species (8-10). In terms of biomass they are dominated by Arctic freshwater fauna (60–90%), whitefish being the most common. Our data supports the view shared by some authors that the structural complexity and stability of northern ecosystems is due not only to the number of species but also to the number of intraspecific forms in whitefish and char which may for practical purposes be treated as independent species (Reshetnikov, 1980, 1995; Pervozvansky, 1986; Savvaitova, 1989; Kitaev, 1993; Chereshnev, 1996; Järvi, 1928; Vuorinen, Piironen, 1984; Nyman et. al. 1991; Svardson, 1998, et al.). In the lakes studied only whitefish displays a variety of forms (3–4 forms) whereas char is represented by a single form. We believe that the ability displayed by whitefish and char to exist in a number of forms compensates for the lack of species diversity and raises the stability of northern ecosystems.

In western Karelia the number of fish in each lake studied increases to 10–14 although practically all fish of the *Salmonidae* family disappear. The only exception to this is Lake Tuulos. Arctic freshwater fish are relatively less common (35% in ichthyomass against 72.5% in Lapland) although the number of species remains unchanged. Generally speaking, whitefish is still the dominant species in many lakes of the region. However, we have exact records of its presence only in Lake Tuulos where it exists in both medium and multi-rakered forms which are also known from other water bodies in Karelia, Finland and Sweden.

In western Karelia the fish population is dominated in terms both of the number of species (5) and of biomass (60%) by boreal-plain species. As well as common established species some new fish such as roach, dace, ide and ruffe were reported in this region. The core of the fish population is formed by perch, roach and whitefish.

Western Karelia has just three boreal-submontane species compared with five in Finnish Lapland (i.e. sea trout and minnow are not present in western Karelia). Similarly, the contribution towards total biomass of these species is a mere 1.5% in western Karelia as against 25.5% in the north.

Significantly, the fish fauna of western Karelia includes southern Ponto-Caspian species such as bream and bleak but these make up only 3.0% in terms of total biomass. It should be noted that the diversity of species (10–14 for each lake) and forms (two of whitefish and two of cisco) is markedly greater in western Karelia than in Finnish Lapland. Similarly, zooplankton biomass increases from 0.6 to1.7 g/m^3 while that of benthos rises from 1 g/m^2 to15 g/m^2. Total ichthyomass increases from 6–15 kg/ha in the lakes of Lapland to 20–50 kg/ha western Karelia (Reshetnikov, 1980; Kitaev, 1984; Ilmast, 1999).

In comparison with North Lapland the trophic chains of water bodies in western Karelia are more complex. Individual trophic groups of fish are usually represented here by several fish species. However, these groups are poorer than those of water bodies located further south where one can find full saturation of trophic chains.

Owing to their well known biological characteristics fish are highly useful for assessing changes in water bodies.

4.5.2. Fish zoogeography of the freshwater bodies of Fennoscandia

According to Berg (1949) the water bodies of Fennoscandia and adjacent territories are located either in the European district of the Arctic Sea province of the Circumpolar subzone or in the Baltic province of the Mediterranean subzone of the Holarctic.

Eighteen lakes located in the Baltic Sea, White Sea, Barents Sea and North Sea basins in Russia, Finland, Sweden, Norway and Estonia were selected on the basis of their large size and high fish populations for the purpose of analysing the composition of fish and other aquatic vertebrate fauna in Fennoscandia and adjacent territories (Table 45).

According to the latest annotated catalogue (1998) of *Cyclostomata* and fish in the continental waters of Russia, 50 freshwater fish and cyclostomes from 16 families and 38 genera occur in the water bodies of Fennoscandia and adjacent regions. The carp family *(Cyprinidae)* is represented by 14 genera and 18 species and the salmon *(Salmonidae)* and whitefish *(Coregonidae)* families together by four genera and nine species. There are 48 fish and other aquatic vertebrate species in the Karelian water bodies of the Baltic Sea basin (lakes Ladoga, Onega, Syamozero and Vodlozero) but only 25 species in those of the White Sea basin, the total number of Karelian freshwater species amounting to fifty. It should be noted that some of these species such as sea sturgeon (*Acipenser sturio*), nelma (*Stenodus leucichthys,* Guldenstadt), skygazer (*Leucaspius delineatus,* Heckel), white-eye (*Abramis sapa),* sabrefish (*Pelecus cultratus),* loach *(Misgurnus fossilis*) and sheatfish (*Siluris glandis)* have not been reported from Finnish, Swedish and Norwegian lakes, although sheatfish did occur in Finland during the last century.*

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* Native populations of sheatfish also in S. Sweden and in Russian Karelia (River Suojujojoki).

Table 45

Occurrence of various fish and other aquatic vertebrate species in large lakes of Fennoscandia and adjacent territories

Nos	Species	Baltic Sea basin							White Sea basin								Barents Sea		North Sea
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1. *Petromyzontidae*																			
1	*Lethenteron japonicum* (Martens)	–	–	–	–	–	–	–	–	–	–	+	–	–	+	+	+	+	–
2	*Lampetra fluviatilis* L.	+	+	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	+
3	*L. planeri* Bloch	+	+	–	+	–	–	+	–	–	–	–	–	–	–	–	–	–	–
2. *Acipenseridae*																			
4	*Acipenser ruthenus* L.	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
5	*A. sturio L.*	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
3. *Salmonidae*																			
6	*Salmo salar m. sebago* Girard	+	+	+	+	+	+	–	+	+	+	–	–	–	+?	–	*	–	–
7	*S. trutta m. lacustris* L.	+	+	+	+	–	–	–	–	–	+	+	–	–	+	+	+	+	+
8	*Salvelinus alpinus lepechini* (Gmelin)	+	+	–	+	–	–	–	–	+	+	+	–	–	+	+	+	+	–
4. *Coregonidae*																			
9	*Coregonus albula* L.	+	+	+	+	+	+	+	+	+	+	+	+	–	+	+	*	–	+
10	*C. pidschian* Gmelin	+	+	+	+	–	–	–	–	–	–	+	–	–	+	+	+	+	+
11	*C. lavaretus* L.	+	+	+	+	+	+	+	+	+	+	–	–	+	+	–	+	+	–
12	*C. wartmanni* (Bloch)	+	+	+	+	–	–	–	–	–	–	–	–	–	–	–	+	–	–
13	*C. maraenoides* (Poljakov)	+	+	+	+	–	–	–	–	–	–	–	–	–	–	–	–	+	–
14	*C. muksun* (Pallas)	–	–	+	+	+	–	–	+	+	+	+	–	–	–	–	–	–	–
15	*Stenodus leucichthys nelma* (Pallas)	–	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–
5. *Thymallidae*																			
16	*Thymallus thymallus* L.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
6. *Osmeridae*																			
17	*Osmerus eperlanus* L.	+	+	+	+	*	+	+	*	*	+	+	+	+	+	–	–	–	+
7. *Esocidae*																			
18	*Esox lucius* L.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
8. *Cyprinidae*																			
19	*Rutilus rutilus* (L.)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	–	+	+
20	*Leuciscus leuciscus* (L.)	+	+	+	+	+	+	+	–	–	+	–	+	+	–	–	–	–	+
21	*L. cephalus* (L.)	+	–	+	–	+	–	+	–	–	–	–	–	–	–	–	–	–	–
22	*L. idus* (L.)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	–	–	–	+
23	*Phoxinus phoxinus* (L.)	+	+	+	+	+	+	+	+	+	+	+	+	–	+	+	+	+	+
24	*Scardinius erythrophthalmus* (L.)	+	+	+	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–
25	*Aspius aspius* L.	+	–	+	+	–	–	+	–	–	–	–	–	–	–	–	–	–	–
26	*Leocaspius delineatus* (Heckel)	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
27	*Tinca tinca* (L.)	+	–	+	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–
28	*Gobio gobio* (L.)	+	+	–	+	–	–	+	–	–	–	–	+	+	–	–	–	–	–
29	*Alburnus alburnus* (L.)	+	+	+	+	+	+	+	+	+	+	–	+	+	–	–	–	–	+
30	*Blicca bjoerkna* (L.)	+	+	+	+	+	+	+	–	–	–	–	+	+	–	–	–	–	–
31	*Abramis brama* L.	+	+	+	+	+	+	+	+	+	+	+	+	+	–	–	–	–	+
32	*A. sapa* (Pallas)	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
33	*A. ballerus* (L.)	+	–	+	+	+	+	–	–	–	–	–	–	–	–	–	–	–	–
34	*Vimba vimba* (L.)	+	–	+	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–
35	*Pelecus cultratus* (L.)	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
36	*Carassius carassius* (L.)	+	+	+	+	–	–	+	–	–	–	–	–	+	–	–	–	–	+
9. *Balitoridae*																			
37	*Barbatula barbatula* (L.)	+	+	–	+	–	+	+	–	–	–	–	+	+	–	–	–	–	–
10. *Cobitidae*																			
38	*Cobitis taenia* L.	+	–	+	–	+	–	+	–	–	–	–	–	–	–	–	–	–	–
39	*Misgurnus fossilis* (L.)	+	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–
11. *Siluridae*																			
40	*Silurus glanis* L.	+	+	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–
12. *Anguillidae*																			
41	*Anguilla anguilla* (L.)	+	+	+	+	–	–	+	–	–	–	–	–	–	–	–	–	–	–
13. *Lotidae*																			
42	*Lota lota* (L.)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
14. *Gasterosteidae*																			
43	*Pungitius pungitius* (L.)	+	+	+	+	–	–	+	+	+	+	+	+	–	+	+	+	+	+
44	*Gasterosteus aculeatus* L.	+	+	+	+	–	–	+	–	–	+	–	–	–	+	+	+	+	–

Okon. table 45

Nos	Species	Baltic Sea basin							White Sea basin								Barents Sea		North Sea
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	15. *Percidae*																		
45	*Stizostedion lucioperca* (L.)	+	+	+	+	+	+	+	*	–	–	–	–	–	–	–	–	–	–
46	*Perca fluviatilis* L.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
47	*Gymnocephalus cernuus* (L.)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	–	+	+
	16. *Cottidae*																		
48	*Triglopsis quadricornis* (L.)	+	+	+	+	–	–	–	–	+	+	–	–	–	–	–	–	–	+
49	*Cottus poecilopus* Heckel	+	+	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	+
50	*C. gobio* L.	+	+	+	+	+	+	+	+	+	+	+	–	+	–	–	+	–	–
	Всего	47	37	36	36	19	20	32	15	17	21	17	17	18	18	14	14	14	20

1 – Ladoga; 2 – Onega; 3 – Venern; 4 –Saimaa; 5 – Syamozero; 6 – Vodlozero; 7 – Pskov-Chud; 8 – Vygozero; 9 – Segozero; 10 – Kuito; 11 – Topozero-Pyaozero; 12 – Vozhe; 13 – Kubenskoye; 14 – Imandra; 15 – Umbozero; 16 – Inari; 17 – Lovozero; 18 – Mjosa.

* Settlers.

Listed in the Red Data Book of Karelia (1995) and in the Red Data Book of East Fennoscandia (1998) are 27 fish species and forms, i.e. Atlantic sturgeon (*Acipenser sturio*), sterlet (*Acipenser ruthenus*), lake salmon (*Salmo salar* m.*sebago*), trout (*Salmo trutta*), lake trout (*Salmo trutta* m. *trutta*), brook trout (*Salmo trutta* m. *lacustris*), artic char (*Salvelinus alpinus*), nelma (*Stenodus leucichthys nelma*), common whitefish (*Coregonus albula)*, Ob whitefish (*C. pidschian)*, Wartmann whitefish (*C. wartmanni)*, chud whitefish *(C. lavaretus)*, muksun (*Coregonus muksun*), grayling (*Thymallus thymallus*), chub *(Leuciscus cephalus),* redfin (*Scardinius erythrophtalmus*), asp (*Aspius aspius*), tench (*Tinca tinca*), skygazer (*Leucaspius delineatus*, Heckel), gudgeon *(Gobio gobio),* white-eye (*Abramis sapa*), blue bream (*Abramis ballerus*) vimba (*Abramis vimba*), sabrefish (*Pelecus cultratus*), spiny loach, (*Nobitus taenia* Linne), wells (*Silurus glandis*) and spotted sculpin (*Cottus gobio*).

The fish and other aquatic vertebrate species studied belong to a number of faunistic complexes (Table 46). Comparison of the faunistic complexes formed by the various representatives of lake fauna, such as fish and parasites sharing a close parasite-host relationship, shows a striking quantitative agreement between the complexes found in the large lakes of different sea basins (Tables 46 and 47). For example, the Upper Tertiary fish-parasite complex is not represented in the Barents Sea, White Sea or North Sea basins although it does occur in the Baltic Sea basin. At the same time, fish of the Pontian faunistic complex are absent only from the Barents Sea basin lakes (Tables 46 and 47) while those of Arctic, boreal plain, boreal submontane and marine faunistic complexes inhabit the lakes of all sea basins.

Comparison of the composition of ichthyofauna from the water bodies of the Arctic Sea province of the European district with that from the Mediterranean subzone of the Baltic province, the Black Sea and Caspian Sea districts shows that the Baltic province is closer in terms of the composition of ichthyofauna, even at the family and generic levels, to the European district of the Arctic Sea province than to the Black Sea and Caspian Sea districts of the Mediterranean subzone (Table 48).

Table 46

Fish fauna of the large lakes of the various sea basins, %

Lakes	Arctic	Boreal submontane	Boreal plain	Ancient Upper Tertiary	Pontian	Marine	Unknown	Number of species
Barents Sea basin								
Inari	35.7	28.6	14.3	–	–	14.3	7.1	20
Lovozero	41.2	17.6	23.5	–	–	11.8	5.9	17
White Sea basin								
Imandra	39.0	22.2	27.8	–	–	5.5	5.5	18
Umbozero	27.6	21.4	27.6	–	–	14.3	7.1	14
Topozero	36.8	21.0	26.3	–	5.3	5.3	5.3	19
Kuito	30.4	21.7	26.1	–	8.7	13.1	v	23
Segozero	31.5	21.0	26.3	–	10.6	10.6	–	19
Vozhe	22.2	16.7	38.9	–	16.7	5.5	–	18
Kubenskoye	22.2	22.2	38.9	–	16.7	–	–	18
North Sea basin								
Mjosa	20.0	20.0	35.0	–	10.0	10.0	5.0	20
Baltic Sea basin								
Syamozero	20.0	20.0	35.0	5.0	20.0	–	–	20
Vodlozero	20.0	25.0	30.0	5.0	20.0	–	–	20
Onega	21.6	18.9	21.6	8.3	13.5	10.8	5.4	37
Ladoga	17.8	15.6	20.0	11.1	20.0	8.9	6.6	45
Saima	25.0	19.5	22.2	2.8	13.9	11.1	5.5	36
Venern	22.2	13.9	25.0	2.8	19.5	11.1	5.5	36

Table 47

Fish parasite complexes in the large lakes of the various sea basins, % (after Rumyantsev, 1996)

Lakes	Arctic	Boreal submontane	Boreal plain	Ancient Upper Tertiary	Pontian	Marine	Unknown	Number of species
Barents Sea basin								
Lovozero	39.0	15.0	43.0	–	–	3.0	–	57
White Sea basin								
Imandra	39.0	19.0	38.0	–	–	4.0	–	72
Umbozero	35.0	19.0	42.0	–	–	4.0	–	67
Pyaozero	26.0	14.0	57.0	–	3.0	–	–	141
Kuito	23.0	4.0	69.0	–	4.0	–	–	111
Kubenskoe	8.0	1.0	70.0	1.0	14.0	–	–	100
Baltic Sea basin								
Syamozero	16.0	4.0	61.0	2.0	16.0	–	–	129
Onega	21.0	12.0	46.0	3.0	15.0	2.0	1.0	260
Ladoga	23.0	5.0	47.0	2.0	19.0	3.0	1.0	146

Table 48

Number of freshwater fish and other aquatic vertebrate families and species in the provinces and districts of Europe (after Berg, 1949)

Families	Arctic Sea province European district	Mediterranean subzone		
		Baltic province	Black Sea district	Caspian district
Petromyzonidae	2	3	2	1
Acipenseridae	1	1	6	5
Salmonidae	9	5	2	4
Thymallidae	1	1	1	1
Osmeridae	1	1	c	–
Umbridae	–	–	1	–
Esocidae	1	1	1	1
Cyprinidae	12	26	40	45
Cobitidae	1	3	7	11
Siluridae	–	1	1	1
Anguillidae	1	1	1	–
Gadidae	1	1	1	1
Gasterosteidae	2	2	2	1
Percidae	2	3	10	4
Gobiidae	–	–	13	11
Cottidae	2	3	1	1
Number of families	13	14	15	14
Number of species	37	52	89	87

In 1949, L.S. Berg wrote that the Baltic province "is remarkable for the relative abundance of *Salmonidae* and marks a transition to the Circumpolar subzone" (p.1252). In his dendrogram of faunistic similarity (Fig. 55) plotted for forty study regions in the Holarctic Y.S. Reshetnikov (1980) describes the water bodies of the Baltic Sea and Arctic Sea provinces (Fig. 63). However, he writes in his monograph that, together with the water bodies of the Arctic Sea province, he purposely took several water bodies from the Baltic Sea basin (the Baltic province of the Mediterranean subprovince after L.S. Berg or, more precisely, the Atlantic-Baltic province of the European-Mediterranean subzone after Banarescu (Banarescu, 1960).

One example of the unsuccessful subdivision of Europe into twenty-five regions on the basis of lake fauna is the monograph 'Limnofauna Europaea' (1967 and 1978 editions) in which it is stated that Fennoscandia and adjacent territories occupy six regions: Tundra (21), Boreales Hochland (20), Nordschweden (22), Taiga (23), Zentrales Flachland (14) and Baltische Provinz (15) (Fig. 64). The large basins of most rivers belong to different regions and some countries, such as England, Ireland, Iceland, Italy and Greece, are also located in different regions. It is clear that the authors of this monograph violated the principle of river and sea basins and the characteristics of lake fauna.

In 1949 L.S. Berg advised S.V. Gerd (1956) that the zoogeographic boundaries were in need of revision and that not just South and Middle Karelia but indeed the whole of Karelia should be regarded as part of the Baltic province. However, this idea of L.S. Berg was never published. As a consequence the revision of zoogeographic boundaries as well as the removal of the Baltic province from the Mediterranean subzone and its incorporation into the Circumpolar subzone have been the subject of ichthyological debate for over fifty years.

The entire lake fauna pattern suggests that the Baltic province should be part of the Circumpolar subzone. The Circumpolar subzone and the Baltic province share a characteristic fauna, e.g. species of *Coregonus*, *Salmonidae* and *Osmeridae;* molluscs, e.g. the freshwater pearl clam (*Margaritana margaritifera* (L.)), the pea clam *Pisidium conventus* Clessin and the clam *P. subtilestriatum* Lindh = *Lacustrina dilatat* Westerlund; relict crustaceans such as *Limnocalanus macrurus* Sars; *Gammaracanhus lacustris* Sars; *Mysis relicta* Loven, *Pontoporeia (Monoporeia) affinis* Lindstrom, *Pallasea (Pallasiola) quadrispinosa* Sars and *Sadura entomon* (L.)); the relict fourhorn sculpin (*Triglopsis quadricornis* (L.)), etc.

The zoogeographic demarcation of Northwest Europe on the basis of lake fauna attempted by various authors is shown in Table 49. Many hydrobiologists (Starobogatov, 1970; Pidgaiko, 1984; Timm, 1987; Popchenko, 1988)

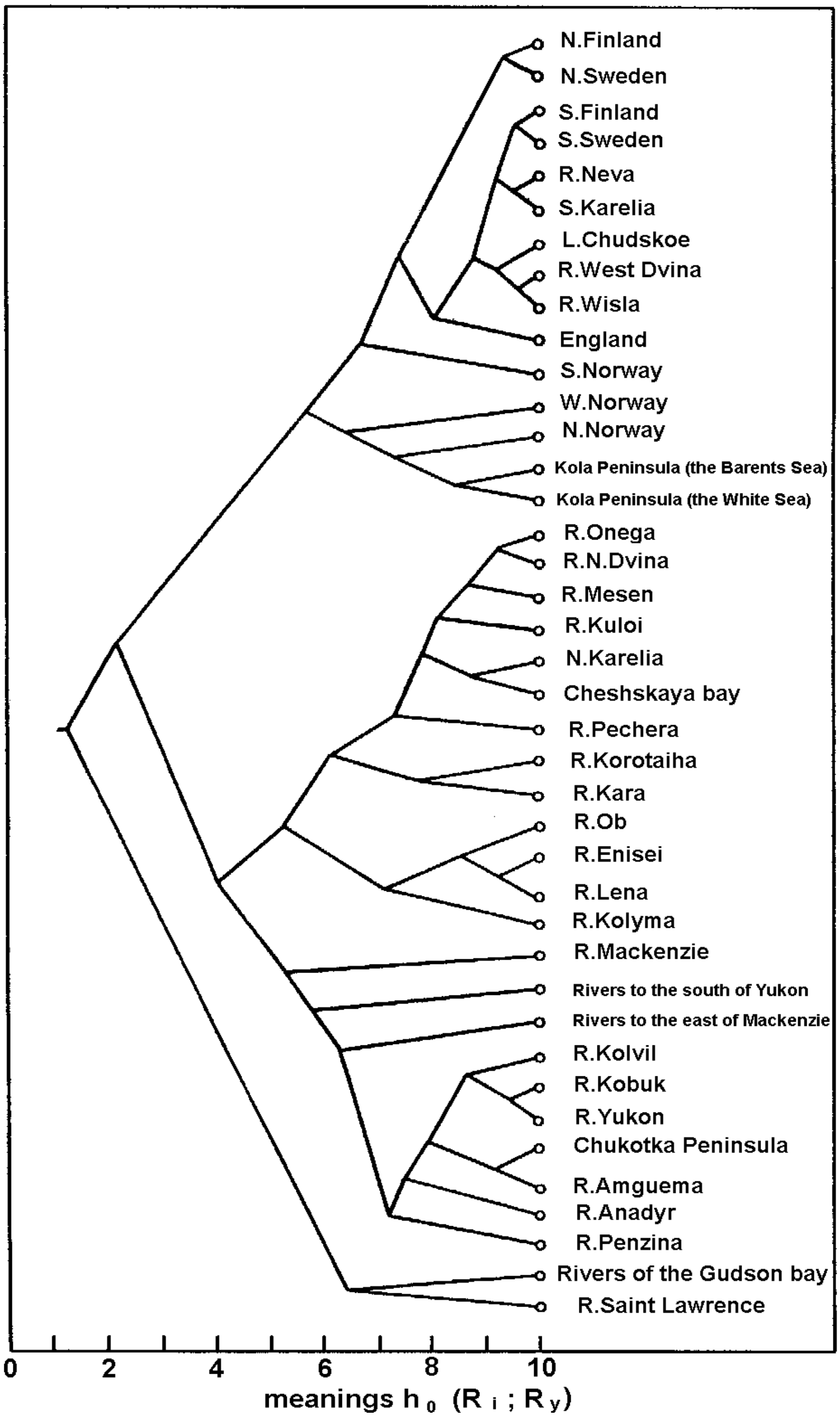

Fig .63. Dendrogram showing the compositional similarity of ichthyofauna in forty areas studied in the Holarctic (N – north, S – south, W – west, L – lake, R – river)

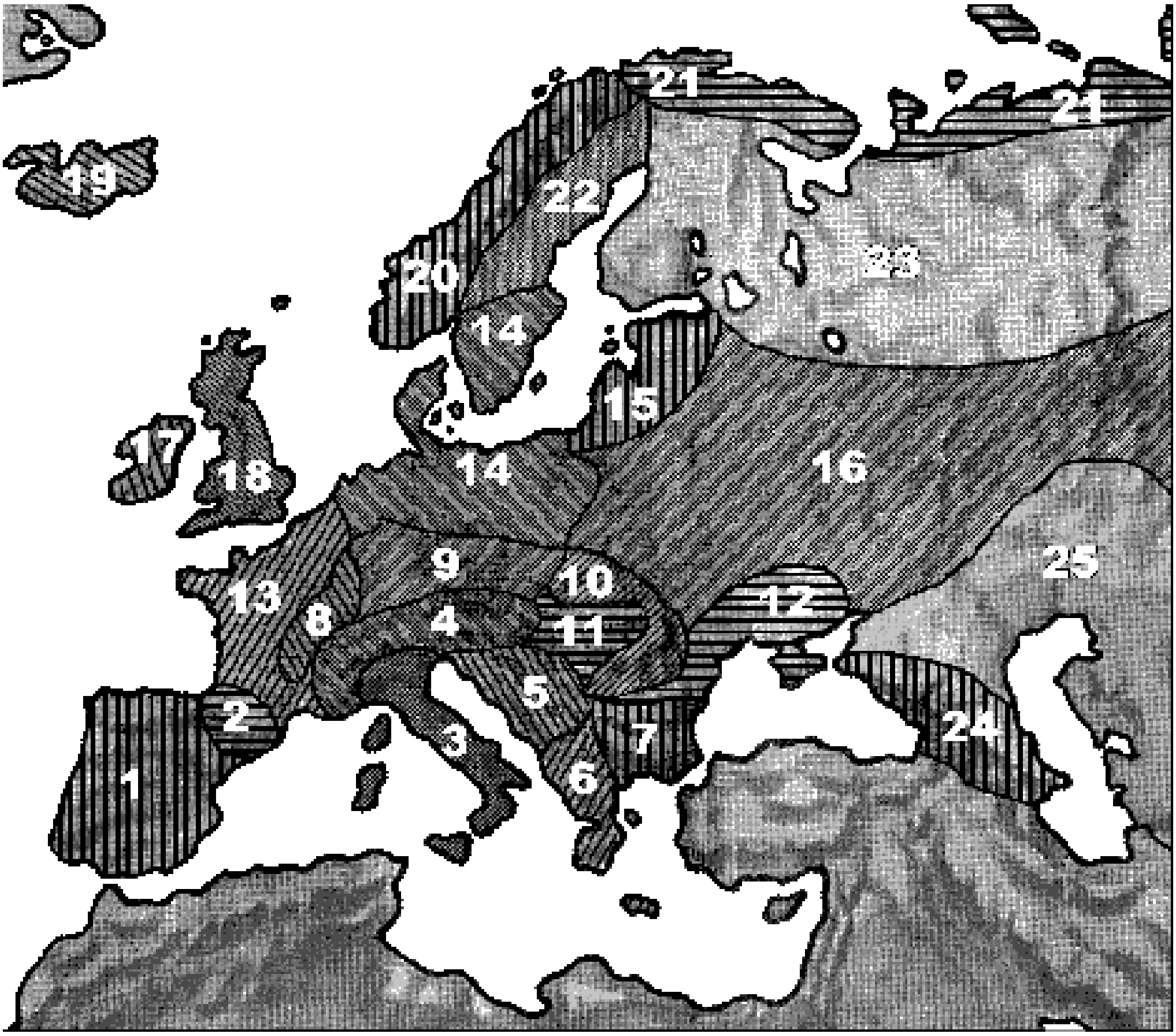

Fig. 64. Limnofaunistic regions of Europe

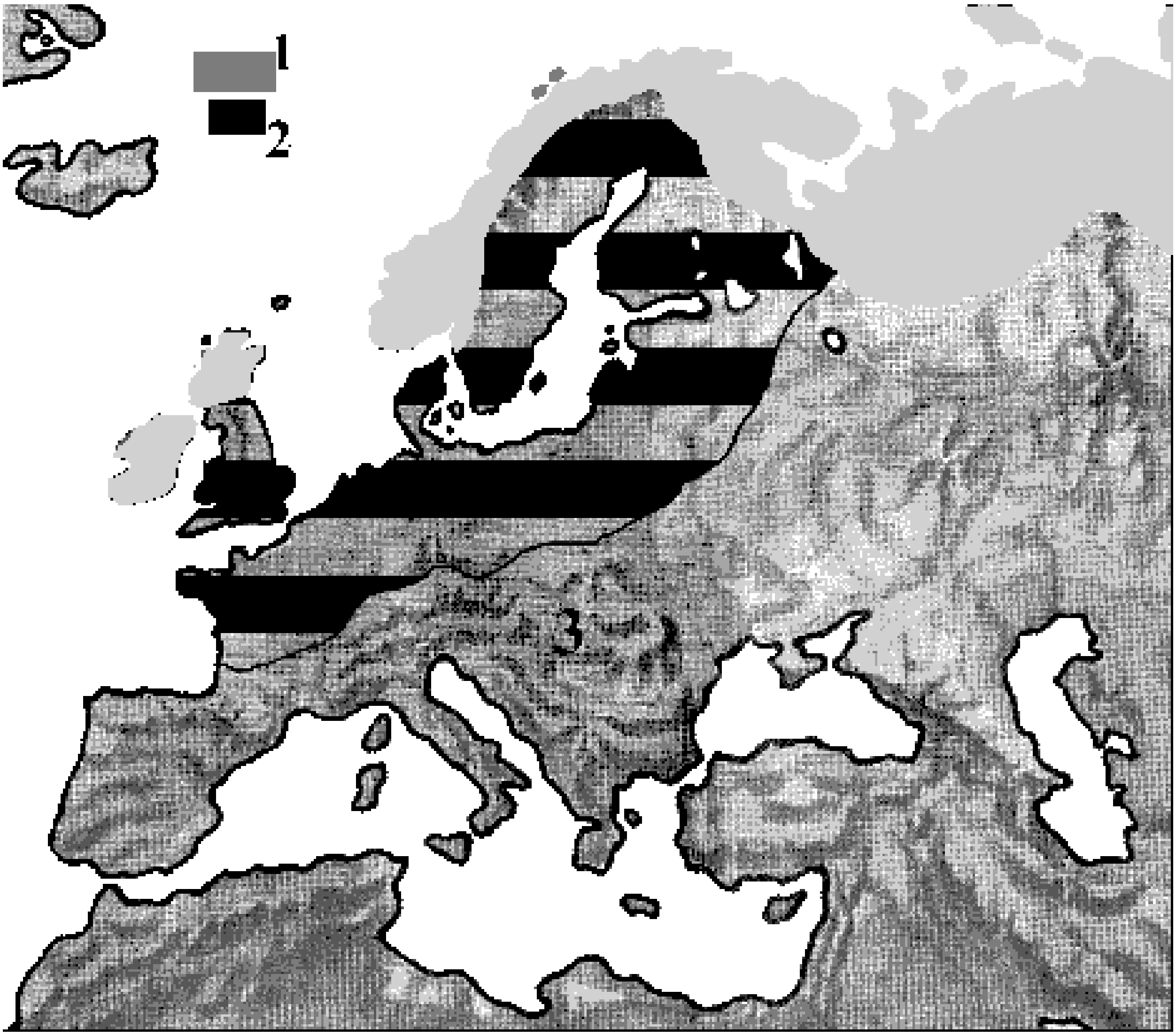

Fig. 65. Zoogeographic demarcation for European freshwater fish. Circumpolar subzone

1. Arctic Sea province, European district. 2. Atlantic-North Sea-Baltic province. 3. Mediterranean subzone

believe that the Baltic province as understood by L.S. Berg (1949) is part of a European-Siberian subzone. This proposal indeed seems more logical. Since the Baltic province (according to L.S. Berg, 1949) has an unique ichthyofauna and lake fauna pattern of its own and was also affected by the most recent glaciation, it should be regarded as part of the Circumpolar subzone (Fig. 65). Karelia and adjacent territories must thus be attached as part of Fennoscandia to the Circumpolar subzone of the Arctic Sea province rather than to the Mediterranean Sea province (Table 49, Fig. 65).

The European district of the Arctic Sea province hosts the water bodies located in the North Sea (southern Norway), Norwegian Sea, Barents Sea and White Sea basins while the Baltic province of the Circumpolar subzone encompasses those in the Baltic Sea basin.

In order to subdivide the region into smaller units such as districts, subdistricts, provinces and subprovinces, fish and other aquatic vertebrate species should be studied more closely together with other representatives of freshwater lake fauna. This research was supported by the Russian Foundation for Basic Research (projects 00-04-48668; 00-04-48671).

Table 49

Zoogeographic demarcation of Northwest Europe on the basis of lake fauna
(North Sea, Baltic Sea, Norwegian Sea, Barents Sea and White Sea basins)

Main targets of demarcation – fish and Cyclostomata					Main targets of demarcation — aquatic invertebrates			
L.S. Berg, 1949	P. Banarescu, 1960	L.A. Kudersky, 1961	Y.S. Reshetnikov, 1980	Authors, 2000	Y.I. Staro-bogatov, 1970; V.I. Popchenko, 1988	M.L. Pidgaiko, 1984	T. Timm, 1987
I. Holarctic zone A Circumpolar section I Circumpolar subzone 1. Arctic Sea province a) European district	A Arctogea I. Holarctic zone 1. Circumpolar subregion	I. Holarctic zone Circumpolar subzone 1. Arctic Sea province a). European district	I. Holarctic zone I. Circumpolar subzone 1. Arctic Sea province 1a. North European district	I. Holarctic zone I. Circumpolar subzone 1. Arctic Sea province 1a. European district 2. Atlantic-North Sea-Baltic Sea province	I. Palearctic zone I. European-Siberian subzone 1. Lapland province 2. Baltic province	I. Palearctic zone I. European-Siberian subzone 1. Tundra region 2. Karelian-Kola region 3. Baltic region	I. Holarctic zone I. Euro-Siberian subzone Regions: a). Kola Peninsula b). Karelia and Onega River basin c). Baltic region and Valdai Upland
B. Meseurasian section III. Mediterranean subzone 1. Baltic province a). Western district b). Eastern district	4. European-Mediterranean subregion a). Atlantic-Baltic province	III. Mediterranean subzone 1. Baltic province b). Eastern district	III. Mediterranean subzone a). Atlantic-Baltic (Baltic) province				

SUMMARY

This publication represents an attempt to sum up extensive data on biotic diversity in Karelia and the conditions under which it has developed. The data was either collected in various areas of the Republic of Karelia during 1997–2000 or taken from existing archive materials. The main results of studies are briefly discussed below.

Biota: conditions of formation

Geological characteristics. Karelia lies on the southeastern margin of the Precambrian crystalline Fennoscandian Shield. Three large, essentially distinct northwest-southeast oriented structural zones may be identified. These are 1) the Karelian craton located in the centre, 2) the Belomorian fold belt lying to the northeast of the craton and 3) the Svecofennian folded province situated southwest of the craton. Biodiversity appears to be affected by two major factors, namely, a gradual decline in the intensity of solar radiation on moving from south to north and the geological characteristics of the territory in question. Uneven areal distribution is demonstrated most clearly by certain rare species which require good growth conditions and are listed in the red data books of East Fennoscandia (1998) and Karelia (1995). Available evidence shows that the specific and cenotic diversity of plants is affected by the following geological and associated geomorphological characteristics of the region: 1) the composition of bedrock and Quaternary cover, 2) the relief and orientation of landforms, 3) the occurrence of faults in bedrock, 4) the presence of special migration corridors generated by macrorelief and 5) the drainage properties and colour of bedrock and soil cover. For biota to evolve and exist normally at least thirty chemical elements must be present in sufficient quantities in the environment. Eleven of them (C, H, O, N, Ca, S, P, Na, K, Mg and Cl) are macrobiogenic while sixteen (I, Cu, Zn, Mn, Co, Ni, Mo, As, B, Se, Cr, Fe, V, Si, F, Sn) are microbioelements. To illustrate this point the attached geological sketch map indicates the locations of thirty-eight rare species with respect to local concentrations of biogenic elements.

Geomorphological characteristics are responsible for a mosaic pattern of sites inhabited by particular species and communities. When compared with the vast Russian plain which rims the region to the south and east Karelia has some structural characteristics of its own that depend on 1) the occurrence of old crystalline bedrock exposures, 2) the predominance of uplifted over troughs, 3) a distinctive style of neotectonic movements along rejuvenated old faults which are responsible for the block structure of relief, 4) the multiple glaciation of the territory during the Quaternary period and 5) the transgressive-regressive evolution of water bodies during the late-glacial and postglacial periods. The above factors have shaped the present relief in which denudation-tectonic landforms are combined with glacial and postglacial erosional and aggradational landforms. The region is demarcated geomorphologically (see sketch map) and the genesis, landforms, vertical and horizontal ruggedness of relief, and thickness and composition of each of the five provinces and nineteen subdistricts are discussed. A comparison is made between the corresponding geomorphological parameters of Karelia and Finland.

Quaternary deposits. Karelia is a model region in terms of the effects of continental sheet glaciation in which various types of glacial and aqueoglacial deposits are well preserved, as too are the landforms they make up. They provide the basis for the formation of modern landscapes. Indeed, the whole history of the stepwise degradation of the most recent Scandinavian ice sheet and associated large water bodies such as the Baltic Sea, the White Sea and Lake Onega is revealed through the presence of compositionally and structurally differing lithomorphological complexes of glacial and aqueoglacial deposits. With these geologic-geomorphological complexes as a foundation, the entire biodiversity of present-day environments of the region was formed during multiple climatic changes following glacial retreat. The Quaternary cover of Karelia varies in thickness from zero to 120–150 metres, the average thickness being 7–12 metres. A sketch map is attached and the main lithomorphological complexes, i.e. 1) glacial depressions, 2) ice-divide zones, 3) aggradational ice-divide uplands, 3) ice margin deposits, 4) limnoglacial and glacial-marine plains, 4) esker ridges, 5) fluvioglacial deltas and 6) outwash plains, are described.

Certain key patterns of changes in biota triggered by major geologic events during the Late Pleistocene epoch, the most recent global climatic cycle, are discussed and a palaeogeographic sketch map is presented. It was during this period that the present-day natural environment of Karelia was formed.

Hydrological characteristics. Karelia is part of the White Sea-Baltic Sea watershed located between the large erosion bases of the White Sea, Lake Ladoga and Lake Onega. The main features of the hydrographic network of the region are 1) the young geologic age of the network, 2) the shallow depth of occurrence of crystalline rocks and the thinness of unconsolidated Quaternary deposits, 3) the occurrence of numerous water-filled tectonic dislocations, 4) highly rugged relief of glacial origin, 5) relatively high levels of atmospheric precipitation combined with low rates of evaporation and 6) the proximity of the main watershed to erosion bases.

The hydrographic network of Karelia is described in detail and relevant sketch maps are presented. Karelia (together with the Karelian Isthmus) has 26 700 rivers and streams with a total length of 83 000 km, and 61 100 lakes that cover a total area of approximately 18 000 km^2. About a half of Lake Ladoga and 80% of Lake Onega, Europe's largest two lakes, are located in Karelia. The lake surface-drainage area ratio of the region is 12% (21% including with the Karelian portions of lakes Onega and Ladoga). This is one of the highest values in the world (Karelia covers an area of 172 400 km^2 including the Onega and Ladoga aquatoria, and 155 900 km^2 exclusive of them).

Analysis of the chemical composition of water samples shows that Karelian water bodies are usually poorly mineralised, have high colour indices and are rich in iron. Surface waters are classified qualitatively on the basis of pH values and the concentrations of organic matter, total phosphorus, chlorophyll-*à* and oxygen (see sketch map attached). These parameters indicate whether water bodies possess good living conditions for hydrobionts and fish.

Soil cover. The soil cover of Karelia is briefly discussed in terms of its importance in the formation of vegetation (the authors use the terminology accepted by FAO UNESCO, 1990). A sketch map of soil cover is attached. The deposits formed during the most recent glaciation are considered to be vital for soil formation. Crystalline rock eluvium is almost entirely absent and primary soils beneath lithophilic vegetation on massive-crystalline rock exposures are very thin. A cool and humid climate, the prevalence of rocks of light mechanical composition occurring close to the crystalline basement and the predominance of coniferous forests are responsible for widespread eluvial-illuvial soil formation at automorphic localities. A highly rugged relief contributes to soil cover diversity.

The soil types common to Karelia include Podzol, Cambisol and Histosol. As these are, with the exception of Cambisols, of low natural fertility forest communities over most of Karelia are poorly productive. Cambisols formed on mafic rock eluvium-deluvium and on shungite shales are the most fertile in the region because they are rich in organic matter and mineral nutrients.

Cambisols lying on shungite shales do not occur outside Karelia. In such areas plant communities and species are highly varied. Of utmost significance are Salic Fluvisols formed along the White Sea coast and Lithic Leptosols that are deposited in northern Karelia. The floristic complexes formed at these locations are most distinctive and the soils discussed are the primary target of protective efforts.

Diversity and current state of ecotopes and of forest, mire and meadow communities

Methods. The term biodiversity is defined in terms of the occurrence of unequally ranking biosystems, biological species, populations, genotypes, biotypes, phenotypes etc. in ecosystems of various taxonomic levels. Biodiversity is divided up into 1) formations (of plants), 2) biocenoses (phyto- and zoocenoses), 3) synusia, 4) consortia, 4) plant and animal species, 5) plant and animal populations and 6) plant and animal genotypes and corresponding biotypes and phenotypes. The authors propose to assess biodiversity at the levels of 1) biosphere, 2) continent, 3) vegetative (geographic, climatic) zone, 4) vegetative (geographic, climatic) subzone, 5) vegetative (geographic, climatic) district (sector), 6) geographic landscape type, 7) biogeocenotic type and 8) microgroup type. The criteria used to assess biodiversity include age, composition, productivity, mosaicity, prolificacy and distribution.

Questions concerning natural biosystem standards and approaches to the protection of their rare and endangered constituents are discussed. Biocenosis-ranking primeval biosystems and the higher ranking biosystems they form are suggested as standards. They are long-lived, hardy and have fully adapted to local environmental and geographic conditions.

Ways of controlling biodiversity in derivative biosystems and major dynamic trends are discussed in connection with wildlife management in taiga forests. The effects of commercial activities on the constituents of forest biodiversity vary according to the type and quality of the activity in question. It is believed that biodiversity in derivative forests can only be controlled by certain commercial techniques.

Present state of the forest cover. Forests are characterised quantitatively in detail on the basis of available state forest management data. Forests in Karelia consist of pine, spruce, birch, aspen and grey alder. Some communities contain varying percentages of Siberian larch, common alder and Siberian cedar (the last-mentioned occurs in artificial stands). Pine covers 63.8%, spruce 25.2%, birch 10.1%, aspen only 0.7% and alder 0.2% of forested area. Growing in natural environments in the southern part of the region is the Karelian birch, a strictly protected species. Lime, maple and elm are occasionally encountered as undergrowth. The maximum age reached by stands is 240–260 years while the most widespread communities are those aged from zero to forty years. These lastmentioned account for 40.6% of total coniferous area and 60.3% of total deciduous forest area. Stands older than 100 years occupy about one third of total coniferous forest area. Karelia displays a variety of forest types. The most common of these are lingonberry *(Vaccinium)* and bilberry (*Myrtillus*) types which together make up some two thirds of total forested land. Stands of quality classes IV – V with density coefficients of 0.5–0.7 predominating.

Assessment of the diversity of forest communities. A hierarchical system of areal units comprising, in order of ascending rank, of biogeocenosis, ecosite, terrain, landscape, landscape district and landscape region is proposed for evaluating the diversity of forest biota. The distribution of various forest types is assessed using an original classification and map. The individual distribution patterns formed by these types are described briefly at the level of geographic landscape type. Their structural characteristics are discussed and the quantitative proportions of the various forest biogeocenoses estimated. Close attention is paid to certain unique and distinctive features of low-mountain, coastal and other forest communities.

Study areas are divided up into general, common, less common, rare and very rare types with respect to the regional diversity of forest biota. These make up 41, 41, 8, 6 and 4% respectively of the forested area of Karelia. Consequently, the region is divided up into a number of zones which are illustrated in the attached sketch map. The data presented provides a basis for the study of biodiversity at specific and cenotic levels and enables scientists to focus on the most valuable parts of the region.

Landscape models of the primeval forests of Karelia. The authors believe that primeval forests should be the primary target of protection efforts. They are rapidly dwindling in size and are becoming fragmented as a result of large-scale commercial felling. The fragments still surviving in Karelia are the westernmost examples of old-growth taiga in Eurasia and the last of significant size in Fennoscandia.

The following landscape models of primeval forests, each differing considerably in terms of intrinsic structural dynamics, are located, mapped and described. They are 1) spruce stands in low-mountain north-taiga landscape (Paanajärvi National Park), 2) pine stands in lithic north-taiga landscape (proposed Keret protected area etc.), 3) spruce forests in highly paludified coastal plain landscape (proposed Pongoma protected area), 4) pine stands in north-taiga denudation-tectonic landscape (Kostomuksha Strict Reserve and proposed Kalevala National Park) and 5) coniferous forests growing in predominantly morainic mid-taiga landscapes (Vodlozero National Park). These provide the key to the conservation of the entire spectrum of diversity in the taiga zone. Elsewhere in Karelia primeval forests have survived as small isolated fragments. Forests transformed by human activities may also be added to this list if they possess unique or rare properties. For example, certain forest communities in the Zaonezhye Peninsula and northern Priladozhye may be used as models because they contain highly varied biota. Although these areas are well-developed agriculturally and managed commercially they nevertheless display unique flora and fauna.

The authors argue that, in accordance with the principle of landscape representativeness, the first territories to be conserved should be the main landscape models (standards) of primeval taiga. In other words, it is desirable to form an areal system of taiga fragments including various contrasting types of forests (geographic landscape types). Several major variants tentatively distinguished for the western taiga zone of Russia are 1) ‘red’ taiga, understood as pine forests growing in pyrogenic aqueoglacial landscapes, 2) ‘black’ taiga formed by spruce stands evolving in low-mountain and morainic landscapes and 3) ‘light’ taiga composed of mixed spuce-pine stands in selka landscapes.

Mire vegetation. The hierarchical structure of mire ecosystems, ranging from mire systems to plant communities, is discussed. Karelia possesses nine of the twenty-two geographic mire comptex types known to exist in Europe. Four of these types occur at the boundaries of their distribution areas (a map of mire distribution is attached). The plant cover of mires is highly varied. Particularly common are complex (ridge-hollow, ridge-pool) sites (facies) formed by several cenoses. A topological-ecological classification of Karelian mire plant communities has been developed and consists of forty-eight associations (many of them divided into subassociations) of four classes divided up into several groups according to the moisture content of habitats. The species composition of each association and subassociation is characterised quantitatively. The systems of classifying mire vegetation currently in use in Karelia and North Europe are compared. Rare and regionally specific mire communities are identified and the importance of protecting them in the form of new SPNAs is stressed.

Mire and paludified habitats. The diversity of paludified and mire habitats in various types of geographic landscapes is analysed for each of the major categories of semi-wetlands: 1) paludified forest lands with up to 30 cm thick peat deposits and mire forest lands with peat deposits thicker than 30 cm, 2) dominant tree formations (pine, spruce and birch stands) and groups of forest types and 3) open mires analysed with respect to their water-mineral nutrition type (eutrophic, mesotrophic and oligotrophic). The method proposed was used to assess the regional distribution of various semi-wetland habitats. In the north-taiga subzone open mires cover a larger area than do forest mires and paludified forests, whereas in the mid-taiga subzone these land categories are of about equal size. In the mid-taiga subzone paludified forest lands clearly dominate over mire lands in plain landscapes. This subzone is shown to have more types of paludified forests than does northern Karelia.

Grasslands. The authors show that meadow ecosystems have never been extensive in Karelia. During the 20th century their total area has fallen by a factor of approximately 2.5 so that today meadows cover just 0.71% of the region. Practically all of these are classified as ‘rare’ or ‘endangered’. Meadows are of great importance for the conservation of many rare animal and plant species. Up to a third of insects and spiders, about 5% of birds (not including species which use meadows for hunting or migration) and up to 15% vascular plant species occur in meadowland. Practically all meadow species are found here at the northern boundary of their distribution areas.

The modern typology of Karelian meadows is discussed with respect to prevailing practice amongst Russian researchers as well as the system of classification for North Europe developed by Lars Påhlsson. About twenty major mineral soil, wasteland, paludified, hygrophytic and coastal meadow formations are distinguished and the whole of Karelia is demarcated on the basis of meadow type. The meadows located in the Zaonezhye are especially valuable since they have no analogues anywhere else in the world. The meadows formed in northern Priladozhye, in the areas of Vodlozero and Segozero, and the vicinity of Lake Paanajärvi are of regional significance. The value of these areas warrants the establishment of SPNAs.

Flora and fauna of terrestrial ecosystems: characteristics and variation trends

Vascular plants. Available evidence indicates that Karelia contains 1631 vascular plant species (including the microspecies of some genera), 926 of which (not including microspecies) are aboriginal. Many rare and endangered species occur close to the boundaries of their distribution areas and should therefore be protected. Listed in the Red Data Books of Russia (1988), Karelia (1995) and East Fennoscandia (1998) are 298 vascular plant species classified in accordance with IUCN guidelines. A floristic analysis of eleven existing or planned SPNAs located along the Russian-Finnish border has revealed a wide spectrum of regional flora. These areas are inhabited by 188 Red Data Book species, i.e. 63 % of the total number for the region. Paanajärvi National Park comprises an unique fragment of north-taiga flora. It is populated by 97 Red Data Book species, many of which do not occur elsewhere in Karelia. The largest number of rare species (102) is reported from the proposed Ladoga Skerries National Park which contains many southern plants not encountered elsewhere in Karelia. It is therefore most important that this park be granted official status at the earliest possible date.

Intraspecific diversity of pine and spruce. Convincing arguments are presented for the study of the intraspecific diversity of tree species. Attention is directed towards the role of such study in the development of selection activities for conserving highly adaptive, resistant populations and the maintenance of forest ecosystem diversity. Contemporary research evidence in this field is analysed. On the basis of the results of a morphological analysis of the characters of cones and seeds and an electrophoretic analysis of isoenzymes, the phenotypic and genetic intraspecific diversity of Scots pine (*Pinus sylvestris* L.) and Finnish spruce (*Picea* x *fennica* (Rgl) Kom.), the two major forest-forming species of East Fennoscandia, are discussed. It is shown that over 95% of genetic variation of these two species occurs at an intrapopulational level. A multivariate statistical analysis was performed and various models were used to divide Scots pine and Finnish spruce respectively into six and twelve separate populations according to the morphological characters of their cones and seeds. Judging by the small degree of interpopulation differentiation, it would appear that each of the species analysed has an integral gene pool.

The authors demonstrate that in order to conserve the gene pools of pine and spruce future efforts should be focused on the location of genetic reserves. The establishment of forest seed plantations using plus selection is an important selection technique for producing genetically improved seeds. In order to assess changes in intraspecific diversity parameters caused by the anthropogenic transformation of nature complexes future studies should investigate the genetic and phenotypic structures of the climax cenopopulations of Scots pine and Finnish spruce.

Floristic demarcation. The flora of the biogeographic provinces distinguished earlier (Mela,Cajander, 1906) are mathematically analysed along with eighteen local flora. Convincing evidence is presented for the existence of a distinct floristic boundary which overlaps the boundary between the north and mid-taiga subzones. As more data become available the old model for the floristic demarcation of Karelia should be revised using the latest methods of comparative floristics. The most efficient method is the comparative analysis of local flora.

Mosses. Earlier evidence and recent data have led the authors to conclude that Karelia contains 442 moss species, which represents half of all bryoflora species in the whole of Russia and Fennoscandia. The distribution of all species is analysed for each floristic district. Bryoflora is most varied in Priladozhye (Kl - 361 species), Zaonezhye (Kon - 313) and the Lake Paanajärvi area (Ks – 298 species). Listed in the Red Data Books of Karelia and East Fennoscandia are 109 cormophyte moss species. Regional bryoflora are shown to be well represented in the largest existing and proposed SPNAs. It is desirable, therefore, to protect these areas. Official status should be granted to the proposed Ladoga Skerries National Park which contains over 60% of the region's bryoflora and 33% of Red Data Book mosses, many of which are not found elsewhere in Karelia. The lists and categories of moss species described in the Red Data Book of Karelia should be revised in light of new data.

Aphyllophoroid fungi play an active part in the decomposition and re-synthesis of organic matter and are, therefore, essential constituents of forest ecosystems. They are also widely used as bioindicators of the condition of forests. 404 aphyllophoroid fungus species from 150 genera, 44 families and 11 orders are known for Karelia. The species composition of this group of fungi was studied for some SPNAs. The largest number of species was found in the Kivach (272, including 28 indicator species) and Kostomuksha Strict Reserves (153 and 32 indicator species). Aphyllophoroid fungi are highly diverse in Paanajärvi National Park (131 and 26), in the proposed Kalevala National Park (108 and 36) and in the Tolvajärvi Reserve (122 and 10). It is considered desirable to continue the study of aphyllophoroid fungi in many parts of Karelia. Nine more species are recommended for the Red Data Book of Karelia.

Lichens. Over a thousand lichen species are now known in Karelia although in many areas lichens have not been studied at all. Lichen flora is most diverse in the much-studied provinces of Karelia ladogensis (803 species), Karelia onegensis (511) and the Karelian part of Kuusamo (486). There are numerous lichens which occur at only a few locations and 77 species are listed in the Red Data Book of Karelia. In the extended list of rare species published in the Red Data Book of East Fennoscandia 85 lichen species are placed in various IUCN categories. As more evidence becomes available it will become desirable to revise the list. Studies of lichen flora in the existing and proposed SPNAs have shown that these areas are of great importance for the diversity of this group of organisms. There are 443 lichen species in Paanajärvi National Park, 317 in the Kivach Strict Reserve, 143 in the Kostomuksha Strict Reserve and 139 in the proposed Kalevala National Park. White Sea coastal and insular lichen flora is extremely varied, 356 lichen species having been reported from the Keret Archipelago and 59 from the Kuzova Island Reserve.

Mammals. The composition and distribution patterns of mammals have changed considerably in North Europe chiefly because of the substantial impact which human activities have had on their habitats. During the 20th century seven additional species were found in Karelia and ten in Finland. Analysis of changes in the distribution pattern and prolificacy of game animals has revealed a highly active population dynamic. Some species tend to migrate northwards while others move southwards and westwards.

Six groups of twenty-four game animal species with population dynamics differing between Karelia and Finland are identified. The authors present convincing arguments for the permanent monitoring of mammal populations and the establishment of permanent and temporary reserves in order to maintain animal populations.

Birds. The bird fauna of Karelia presently consists of 291 species, of which 210 species are known to nest here. Recent studies in certain areas has shed more light on the distribution and population levels of some species. Many bird species occur near the boundaries of their distribution areas and are in need of protection. 47 species are listed in the Red Data Book of Karelia and 50 in the Red Data Book of East Fennoscandia. Strictly protected areas were established in order to maintain bird diversity, the nine most valuable sites being included in the catalogue 'Key ornithological areas of international significance in European Russia' (2000). In addition, two wetlands were added to the Ramsar Convention Prospective List (2000).

A landscape-ornithological demarcation of Karelia was undertaken and the region was divided into sixteen districts. The 'local fauna' method was used in order to describe them. Over seventy local fauna complexes were studied and birds were split up into five groups according to their status within each local fauna. Each landscape-ornithological district is characterised briefly. The authors present convincing arguments to show that new SPNAs are needed in order to maintain the prolificacy of rare bird species.

Insects. Some 8 000 insect species have been recorded so far from the present territory of Russian Karelia but this list is clearly incomplete. The corresponding figure for Finland, with its similar natural environment, is about 20 000 species. From the perspectives of both taxonomic coverage and geographical distribution the study of Karelian insect fauna is unsystematic and incomplete. Most records originate from the southern part of Karelia (*Kon* and *Kol* provinces) and in every province faunistic records of insects are the result of studies of only relatively small specific areas. In the northernmost part of the Karelian Republic the only well studied area is that around Lake Paanajärvi. Only quite recently were large scale entomological investigations also carried out in northern and central Karelia in the territories of the existed and proposed national parks and reserves.

In this article the authors attempt to summarise all relevant records made in Russian Karelia since 1950 concerning four insect orders: Diptera (about 1 500 species) Coleoptera (1 278), Lepidoptera (1 194) and Hymenoptera (739). These records were collected from three sources: (1) the authors' own collections, (2) published material and (3) unpublished or partly published information relating to entomological excursions by Finnish entomologists during 1992-1993. Insects have been studied most thoroughly in Petrozavodsk surroundings, in the Kivach Nature Reserve and in Paanajärvi National Park. On the basis of these studies rare and endangered insect species are listed in the red data books of Karelia (255 species) and East Fennoscandia (218 species). A large number of species were found only in southern Karelia. A large quantity of new data on rare and endangered insect species would make an important addition to the next edition of the Red Data Book of Karelia. In order to protect them a network of protected areas of different range taking in the full diversity of natural habitats should be established throughout the whole territory of the Republic of Karelia.

Flora and fauna of aquatic ecosystems: characteristics and variation trends

By 2000 *phytoplankton, periphyton, zooplankton and macrozoobenthos* had been studied in over one thousand lakes and reservoirs and seventy rivers and creeks in Karelia. These were shown to be inhabited by almost 700 species and forms of phytoplankton and periphyton, 652 zooplankton taxa and 138 planktonic protozoan taxa, together with 1 500 species and forms of lakebed and riverbed animals and 54 fish and fish-like animal species.

The composition of ichthyofauna in eighteen of the largest lakes of Fennoscandia and adjacent territories located in the Baltic Sea, White Sea, Barents Sea and North Sea basins is discussed.

Although hydrobionts are diverse, many species are rare and in need of protection. Listed in the Red Data Books of Karelia (1995) and East Fennoscandia (1998) are: aquatic invertebrates: molluscs *Amniola steini, Margaritifera margaritifera;* crustaceans *Gammaracanthus lacustris* and *Sadura entomon;* aquatic insects: mayflies *Brachycercus harrisella* and *Paraleptophlebia werneri;* dragonflies *Aeschna crenata, A.viridis, Libellula fulva* and *Ophiogomphus serpentimus;* stoneflies *Isogenus nubecula, Isoperla difformis* and *Protonemura intricata;* caddis flies *Arctopsyche ladogensis, Glossosoma nylanderi, Semblis atrata, S.phalaenoides* and *Asynarchus thedenii;* aquatic Hemiptera *Gerris najas* and beetles (a few species that live in water). Also listed in the Red Data Book of Karelia (1995) are fish (twenty-seven species and forms).

General conclusion. This volume comprises the first regional survey of biotic diversity in Karelia. It both qualitatively and quantitatively describes the conditions of formation and the specific and cenotic diversity of terrestrial and aquatic biota studied under a special programme covering most of the region. It also assesses the possible consequences of anthropogenic transformation. No book of this kind has previously been published for the European part of the Russian taiga zone. A GIS-based survey of Karelian biodiversity based on this data is obviously required in order to monitor anthropogenic changes in biota caused by human activities.

Concise dictionary of terms used

Aphyllophoroid fungi. A group of fungi which was formerly classified as part of the order Aphyllophorales Ray but now belongs to several orders in modern systems.

Biocenosis. A community of organisms that constitutes a biogeocenosis or a stable system of organisms which exists in a certain area or in part of a water body.

Biogenic elements. Chemical elements vital for the existence and evolution of biota.

Biogeocenosis. A complex of homogeneous natural phenomena (atmosphere, rocks, plants, animals, microorganisms, soil and hydrological conditions) in a particular area. The constituents of the complex interact in their own way and exhibit characteristic types of metabolism and energy exchange between one another and with other natural phenomena. The complex is a constantly changing and evolving, internally contradictory dialectical integrity.

Biotope. An ecologically homogeneous constituent of a biocenotic environment which corresponds to a phytocenosis or its components and provides a habitat for one or other animal or plant species.

Biotype. A complex of phenotypes that belong to a certain genotype.

Cenopopulation. A complex of individuals of a species in a community.

Climax. A final, relatively stable phase in the natural evolution of a biocenosis which perfectly fits growth conditions.

Consortium. A unit of biocenotic structure; a basic energy transformation cell in an ecosystem which includes an individual autotrophic plant or autotrophic plant population and individual species or species populations related to it both trophically and topically, i.e. through the habitat.

Cover. A younger sequence of bedded sedimentary and volcanogenic rocks resting on an older basement. Originally the beds were horizontal but during subsequent evolution they may have been deformed by folding.

Craton. A relatively consolidated portion of the Earth's crust of the continental type.

Ecosystem. A rank-free concept understood as a stable system of living organisms and their environment (i.e. abiotic and biocenotic conditions) in which an internal cycle of substances occurs and which is involved in their external cycle. The terms 'ecosystem' and 'geosystem' are essentially equivalent and may be considered as synonyms.

Exhausted biocenosis. Synonym for climax biocenosis.

Fold zone. A portion of the Earth's crust in which rock beds are folded.

Formation. A complex of phytocenoses characterised by the same plant species that dominate in the main vegetative layer. **Gene pool**. A complex of species population genotypes.

Generation. There are two essentially similar definitions of generation: a) a group of individuals equally related to their common ancestors, i.e. a direct progeny formed by individuals of the previous generation; b) a group of individuals of a population equidistant from their common ancestors.

Genotype. A complex of all the hereditary properties of an organism.

Geographic landscape. An ecological system (geosystem, areal nature complex) dominated by genetically homogeneous, structurally and metabolically interrelated, and interdependent combinations of landforms, Quaternary deposits, soils, microclimates, the hydrographic network and phyto- and zoocenoses evolving under the same climatic conditions. Each type of landscape exhibits specific interrelations between its taxonomically lowest constituent ecosystems and within these ecosystems between their components. Each type of geographic landscape is characteristically dominated by certain genetic landforms and Quaternary deposits, soil types, genera and species, a hydrographic network of a particular composition, structure and density, individual types of microclimate, certain types of phytocenoses of basically one single primeval formation and specific zoocenoses evenly distributed in space.

Greenstone belt. A long, narrow, structurally complex zone dominated by volcanogenic rocks and metamorphosed to greenschist grade.

Hylotrophs, hylotrophic. Organisms (including fungi) that feed on wood tissue.

Macromycetes. Fungi with macroscopic fruit bodies.

Microgroup. Structural units formed by the horizontal subdivision of a biogeocenosis. These differ from each other in composition, structure, linkage pattern, metabolism and energy exchange.

Mycobiota. A term which combines the diversity of fungi and fungus-like organisms.

Phenotype. A complex of all the external and internal structures and functions of a given organism which can be described and studied by morphological, anatomical and physiological methods. A phenotype is the manifestation of a genotype.

Phytocenosis. A community of plant organisms that are part of a biogeocenosis and form their own internal medium.

Population. A relatively isolated long-lived population of individuals of a given species which occupies a certain area and can reproduce. Each population forms a morphophysiological type which is used to distinguish it from neighbouring populations.

Primeval biocenosis. Synonym for climax biocenosis.

Saprotrophs. Organisms (including fungi) that feed on dead plant and animal tissue.

Selka, selga - denudation tectonic ridge.

Station. Part of a biotope, the habitat of an individual animal, a family of animals or an animal species. Can overlap the phytoenvironment of a phytocenosis, a microgroup and the individual constituents of phytosystems.

Syncline, synclinal structure. A fold in which the core contains the stratigraphically younger rocks; its form is generally upward concave.

Synclinorium. A composite synclinal structure of regional extent composed of lesser folds (synclines).

Synusium. An ecologically and spatially isolated part of a phytocenosis which consists of plants of one or several similar life forms.

Zoocenosis. A complex of interrelated animal species existing in space.

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