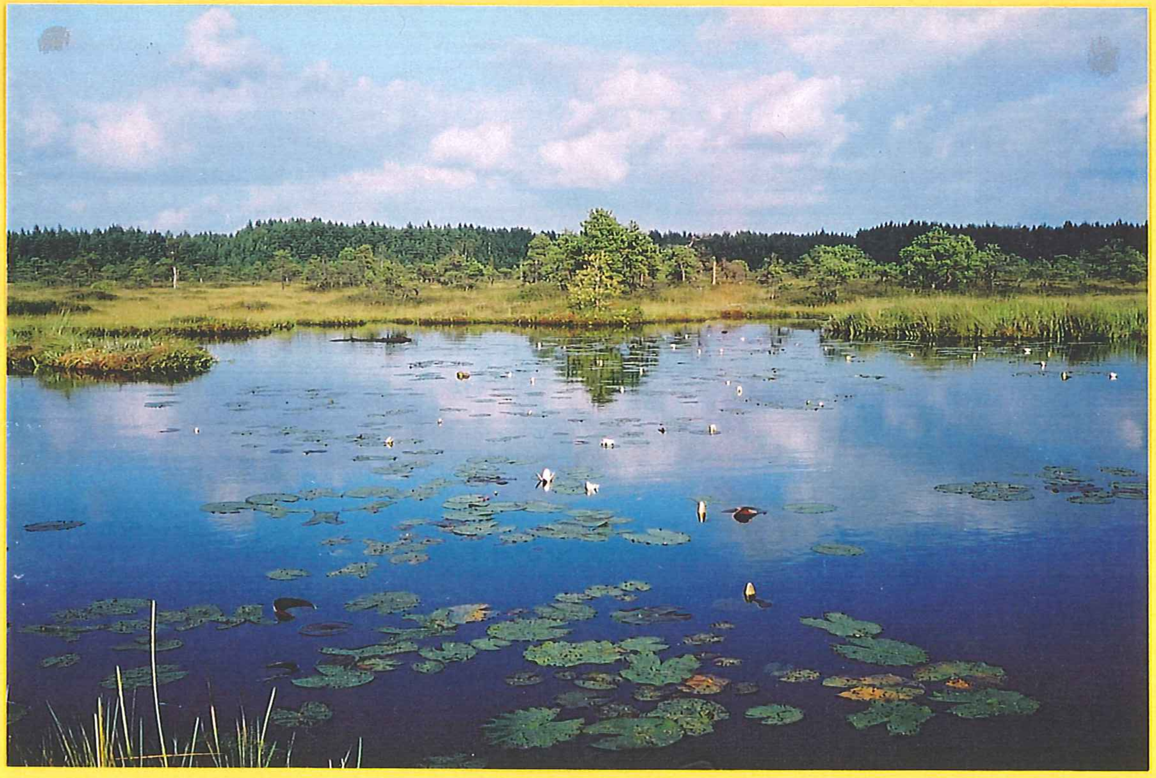
XXVIII MOOREXCURSION (BOG EXCURSION) OF THE INSTITUTE OF PLANT SCIENCES, UNIVERSITY OF BERN INSTITUTE OF ECOLOGY, TALLINN UNIVERSITY

ESTONIA – LAND OF BOGS

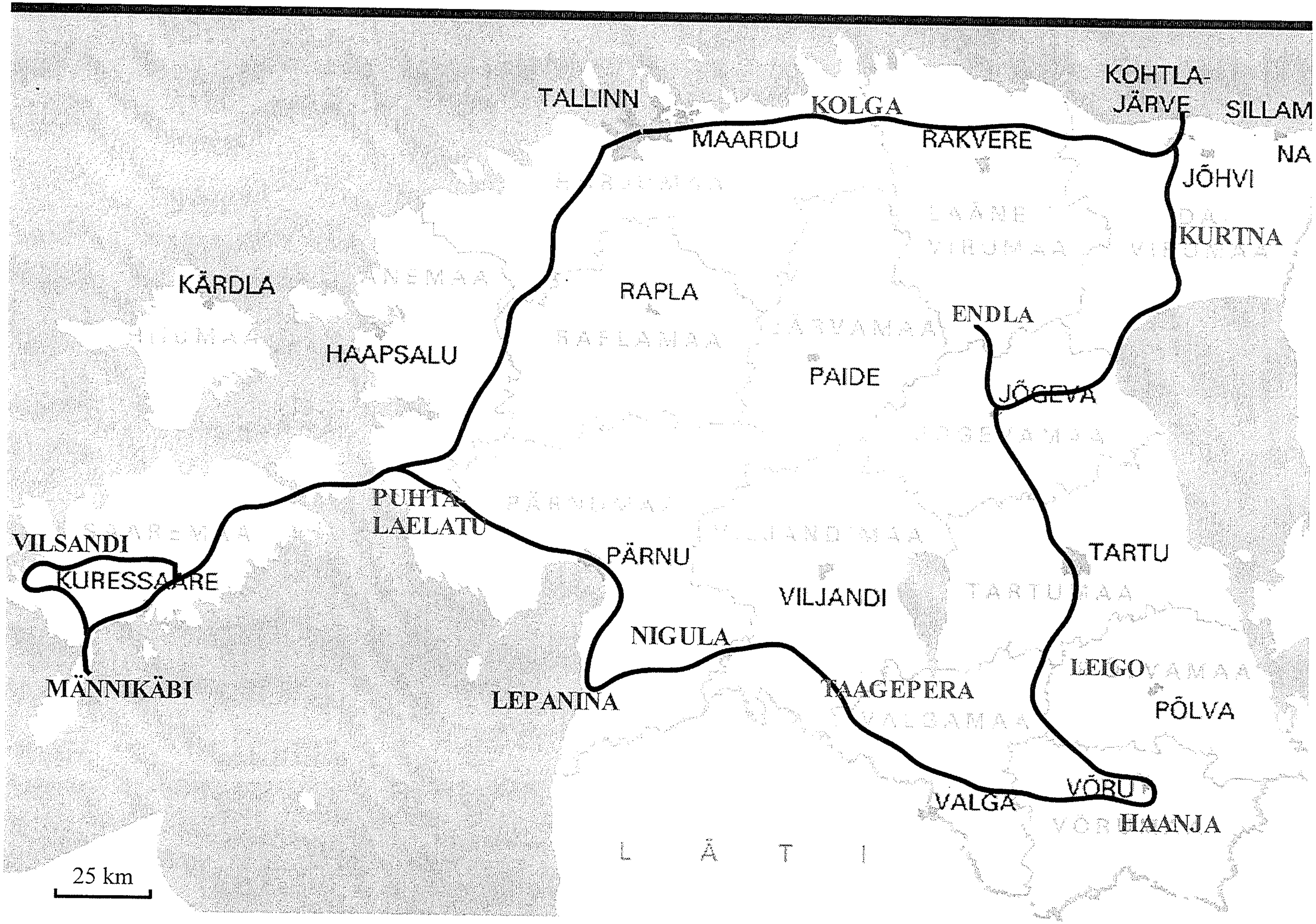
21-29 August 2004



EXCURSION GUIDE

Compiled by Liisa Puusepp, Annika Mikomägi & Tiiu Koff

Organizers and invited speakers: Tiiu Koff, Mihkel Kangur, Jaan-Mati Punning, Edgar Karofeld, Jaanus Terasmaa, Mati Ilomets, Are Kont, Raimo Pajula, Tsipe Aavik, Kai Kimmel, Agu Leivits, Marika Kose, Mari Reitalu, Inge Vahter, Galina Kapanen, Kris Heinsoo



Overview map, XXVIII Moorexcursion (bog excursion)

INDEX

ITINERARY

Saturday, 21 August
Arrival to Tallinn (www.tallinn.ee). Meeting point at the Sakala Centre 14.00.
Excursion to the Lahemaa National park (www.lahemaa.ee). Kostivere stone cist barrow. Welcome party and sauna in Raudsilla (www.raudsilla.ee). Accommodation in Kolga (www.kolgahotell.ee).

Sunday, 22 August
Lahemaa National Park. Viitna Pikkjärv and Linajärv lakes - vegetation history and lake level-changes. Viru peatbog. Võsu. Altja. Sagadi forest-museum. Dinner in "Viitna kõrts".Accommodation in Kolga.

Monday, 23 August
North-Estonia. Alvar landscape. Ontika – highest point of the Baltic Clint. Kurtna lake district - impact of alkaline pollution on lake and mire ecosystems. Lake Peipsi - the fifth largest lake in Europe. Dinner in Härjanurme fishing farm. Accommodation in Jõgeva hostel Virtus (www.hot.ee/virtus) and Endla Nature Reserve

Tuesday 24 August
Endla Nature Reserve (www.endlakaitseala.ee) Investigations on mire ecosystems: hydrological regime, methan emission studies, competition or cooperation between Sphagnum species, ACCROTELM project. Tartu University, Botanical Garden (www.ut.ee/botaed), Otepää Landscape Reserve (www.otepaaloodus.ee). Dinner and accommodation in Leigo farmhouse (www.leigo.ee).

Wednesday 25 August
Lake Juusa history. Haanja Nature Reserve (www.haanjapark.ee). Suur-Munamägi - highest point in the Baltic (318 m) and thickest peat deposit (17 m) in small kettlehole Vällamägi. Dinner and accommodation in Taagepera castle (www.taageperaloss.ee)

Thursday, 26 August
Nigula Nature Reserve (www.loodus.ee/nigula). Studies on peat increment, climatic reconstructions and vegetation history. Dinner and accommodation in Lepanina hotel (www.lepanina.ee).

Friday 27 August
Rannametsa-Soometsa Nature Reserve (www.luitemaa.eoy.ee) Puhtu-Laelatu Nature Reserve. Kõmsi stone cist barrow. Trip to Saaremaa Island. Dinner and accommodation in Männikäbi hotel (www.saarehotell.ee).

Saturday 28 August
Protected plant species. Kaali meteoritic crater (www.muinas.ee/ecp/kaali/en/index.html) Viidumäe Landscape Reserve (www.viidumae.ee): minerotrophic fen - place for 40 various orchids, endemic species. Complex profile - element in landscape studies. Vilsandi Landscape Reserve Center (www.vilsandi.ee). Dinner in Lümanda Söögimaja. Accommodation in Männikäbi hotel.

Sunday 29.08.04
Return to Tallinn (at latest about 14.00).

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About Estonia - Short Overview

SOME FACTS

Full country name: The Republic of Estonia

Area: 45,226 sq km

Population: 1.36 million

Density of population: 31,9 people per km^2

Capital City: Tallinn

People: Estonian (65%), Russian (28%), Ukrainian (2.5%)

Language: Estonian

Religion: 23% Christian (Lutheranism and Orthodoxy)

Government: Parliamentary republic

Currency: Estonian crown (kroon)

GDP: US$15.52 billion

GDP per capita: US$11,000

Major Industries: Food, clothing, oil shale, metals, woodworking

Major Trading Partners: Finland, Sweden, Germany, Latvia, Lithuania

Member of EU: Yes

Estonia is the northernmost and smallest of the Baltic states - it's about the size of Switzerland. To the west are the Baltic Sea and the Gulf of Riga, and the Gulf of Finland lies to the north. Helsinki is just 80 km away across the Gulf of Finland; St Petersburg is 320km east of Tallinn, Estonia's capital, which is on the north-western coast. Estonia's neighbours are Russia in the East, Latvia in the South, Sweden in the West and Finland in the North across the Gulf of Finland. Islands make up nearly 10% of Estonia's territory; the biggest are Saaremaa and Hiiumaa, both off the western coast. Forests cover nearly half the country, and about a quarter of Estonia is wetland - some of the peat bogs are 6m deep.

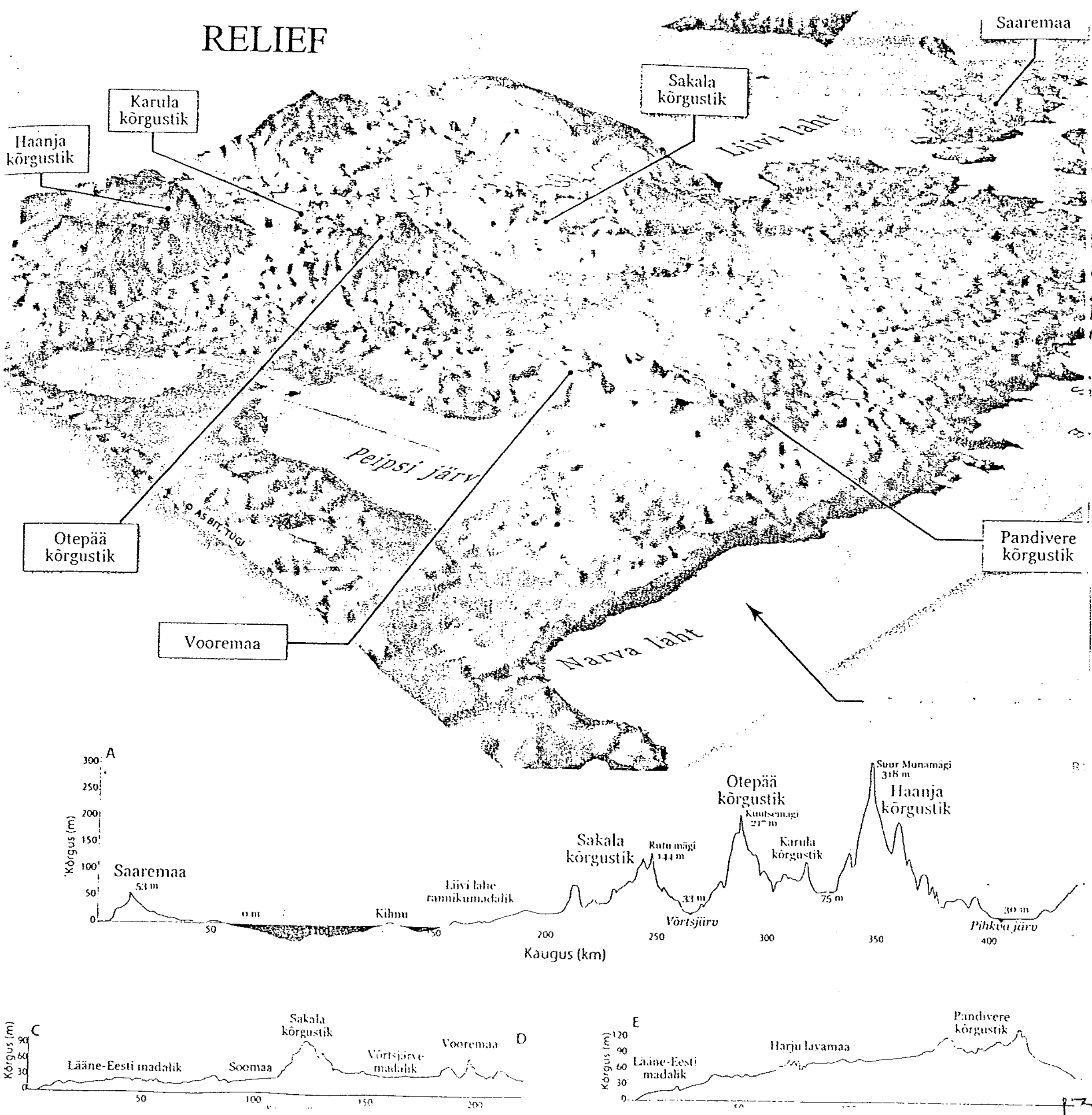
NATURE

As a part of the East European Plain, Estonia is a flat territory, where uplands and plateau-like areas alternate with lowlands, depressions and valleys. Over 60 per cent of the country's territory lies at an absolute height of 0 to 50 meters and only one tenth has an elevation over 100 meters above sea level. The bases of the uplands of Estonia are usually 75–100 m above sea level. However, it is the southeast which is both the highest and topographically most variegated region in Estonia. The highest point in Estonia and the Baltic States, **Suur Munamägi Hill** (318 m), is located in the middle part of the **Haanja Upland**.

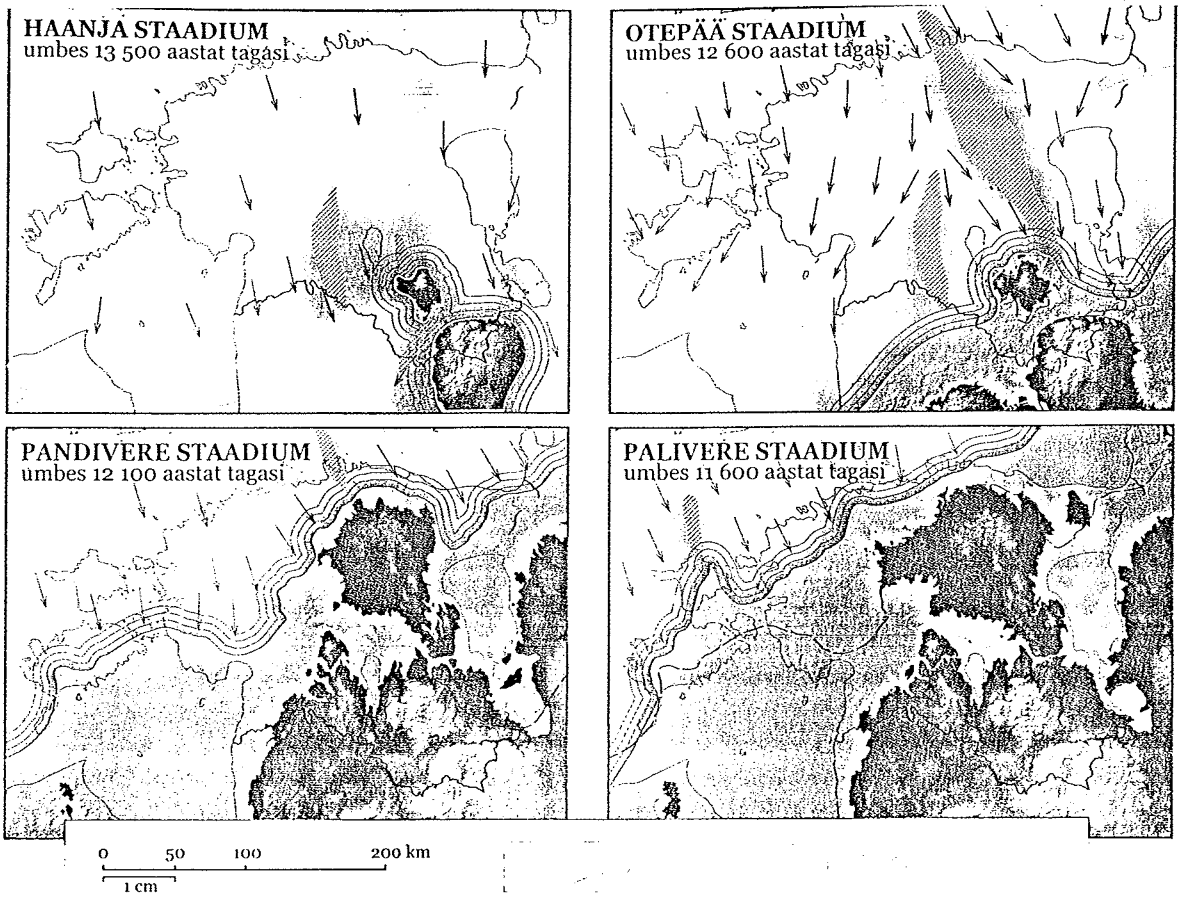
Higher areas include also the plateaus. The **Harju** and **Viru plateaus** are located in northern Estonia and bordered on the north by the steep escarpment of the **Baltic Klint**. Both plateaus are about 30–70 m above sea level. The Ugandi Plateau (40–100 m a.s.l.) in southern Estonia is a sandstone plateau, cut by ancient valleys and bordered by high escarpments. Other relatively high areas are the Central-Estonian Plain (60–80 m a.s.l.) and Kõrvemaa (50–90 m a.s.l.).

The Lowlands are the plains reaching less than 50 m above sea level that have been flooded by the Baltic Sea, ancient Lake Peipsi and ancient Lake Võrtsjärv. The lowlands cover nearly half of the Estonian territory. The largest lowlands are located in western Estonia.

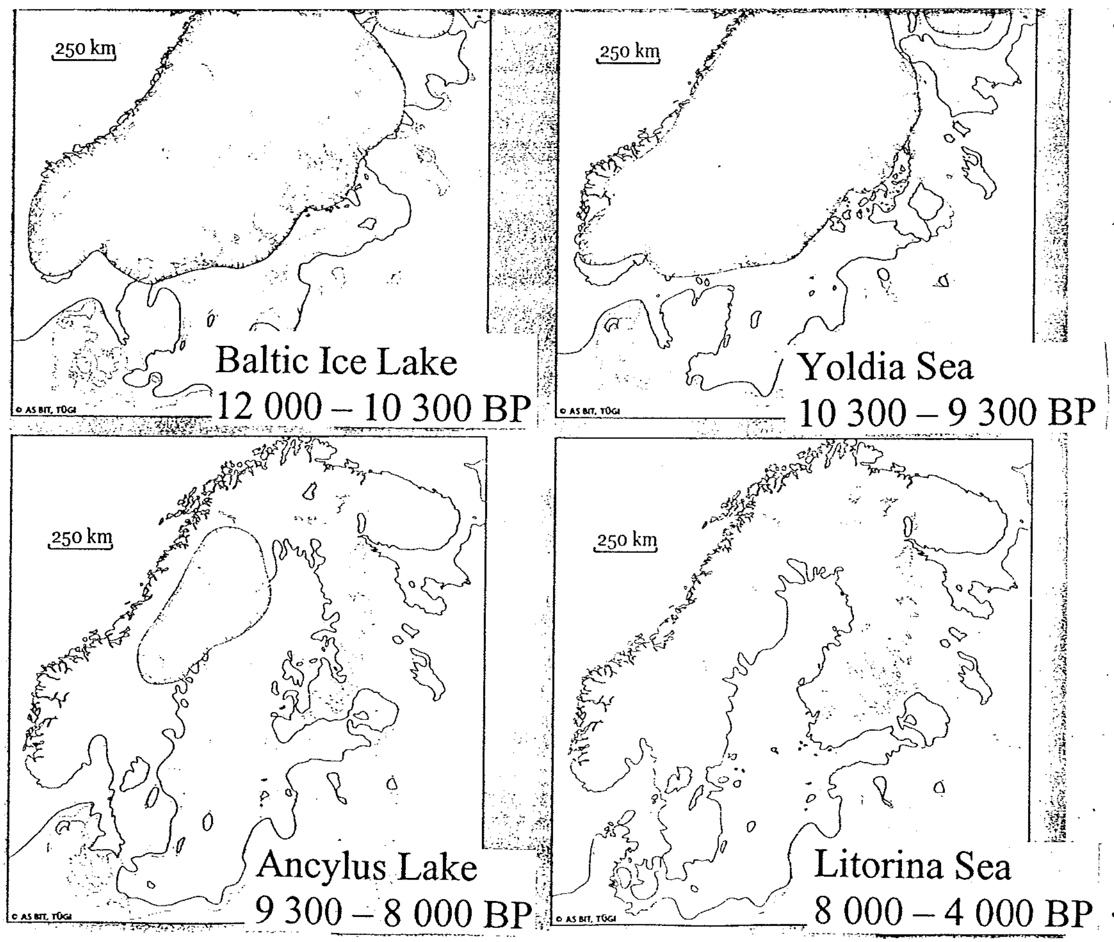
RELIEF



ICE-SHEET REGRESSION



THE BALTIC SEA AND ITS DEVELOPMENT



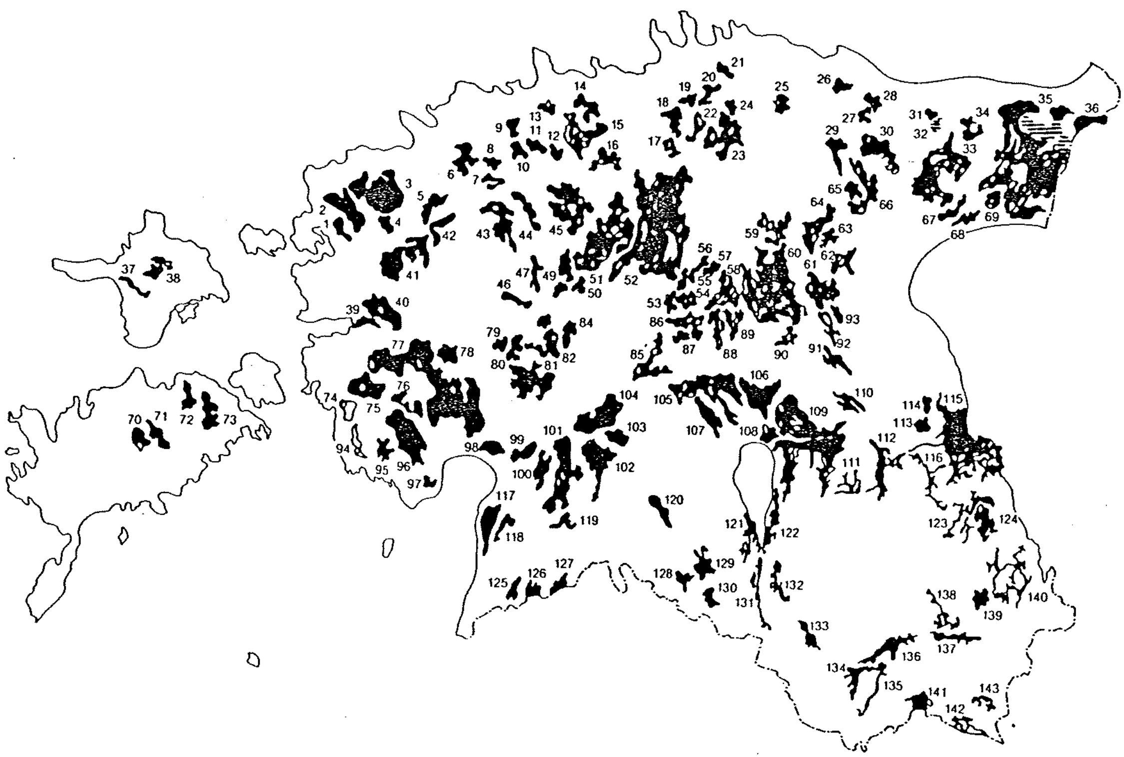
Estonia's rich flora includes 1470 varieties of indigenous plants, while its fauna features thriving populations of large European mammals, among them roe deer, elk, and wild boar. Beaver, lynx, wolf, brown bear, grey seal, and ringed seal are relatively common as well. One of the unique sights of the Estonian forest is the European flying squirrel. Of the 333 recorded bird species, 222 breed in Estonia, among others capercaillie, black stork, and all together at least 400 pairs of eagles. Estonia also has 10 species of rare and protected amphibians.

At least **10 per cent of the Estonian territory is subject to the environment protection**. The most important protection areas are resting and recreation areas for migratory birds, mainly seashore wetlands, and chaste woodland and wetland areas. The preservation of traditional cultural landscapes is important as well.

Forest covers around one half of Estonia. The most common types of tree are pine, spruce and birch. The forests are rich in wildlife. Forest management and wood production are particularly important for the Estonian economy. In around one third of all forests various environmental rulings apply. In such protected forests you can come across types of primeval forest cover which have long ago disappeared from other parts of Europe.

Estonia is a country of thousands of lakes. The largest of these is Lake Peipsi which is the fourth largest freshwater lake in Europe. Most of Estonia's lakes are small and are to be found in the south of the country. Larger lakes such as Lake Peipsi and Lake Võrtsjärv are rich in fish. In Lake Peipsi you can find rare species of fish such as the lake whitefish and the Peipsi smelt. Võrtsjärv is famous for its catches of pike-perch and eel, which are regarded as a delicacy.

About one fifth of Estonia is covered with marshes and bogs, and most of these are to be found in the central and eastern parts of the country. The best place to see marshes is in the Soomaa National Park in Western Estonia. Soomaa indeed means "Bogland" in Estonian and impressive bogs cover the majority of the park with the thickness of the peat layer reaching up to 7 metres in some places.



Estonian mires with the surface area >1000ha (Allikvee, 1995)

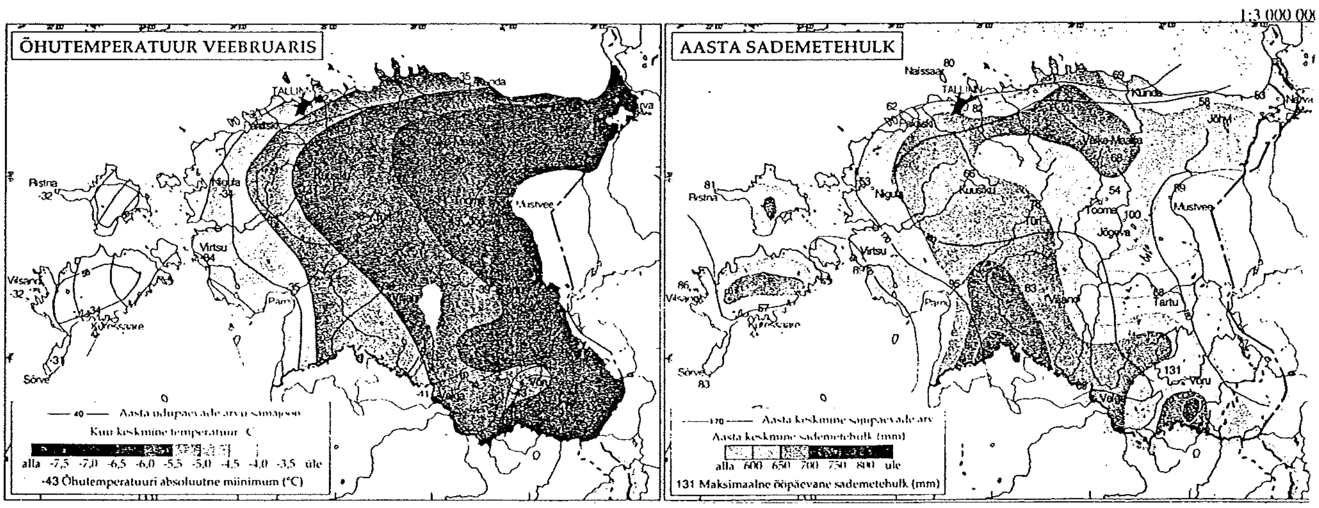
CLIMATE

As in other northern countries, seasons vary widely in Estonia. The length of the longest day in summer is over 19 hours, while the shortest winter day lasts only six hours. Estonia, on the coast of the Baltic Sea, is at the same latitude in Europe as central Sweden and the northern tip of Scotland. In North America, the middle latitude of Estonia passes through the Labrador peninsula and southern coast of Alaska. However, due to the influence of the Atlantic Ocean and Gulf Stream, the weather in Estonia is considerably milder than the continental climate characteristic of the same latitude.

The climate is on the cool and damp side of temperate, verging on continental as you move inland where, in winter, it can be a few degrees colder than the coast or, in summer, a few degrees warmer. The main factor shaping the differences in air temperatures between different regions in Estonia is the Baltic Sea. In winter it keeps the coastal areas much warmer than the inland. **The average air temperature in January is –6° to –7°C in Central and East Estonia and –2° to –4°C in West-Estonia.** The coldest month is February. **The average temperature in July varies between 16.0°C and 17.4°C.** The coolest areas are located on the uplands, the warmest on the coasts of shallow inland seas, such as Pärnu Bay. The highest air temperature, 35.6°C, was measured on 11 August 1992 in Võru, the lowest, –43.5°C, on 17 January 1940 in Jõgeva.

The annual average of the relative air humidity is 80–83%. It is higher in winter and at its lowest in May, being 70% on average. Rain is heaviest in September and lightest in spring. **The annual average precipitation varies between 550 and 800 mm.** The maximum recorded annual total amount of precipitation has been 1157 mm, with a maximum monthly amount of 351 mm, and a maximum twenty-four-hour amount of 148 mm. The snow cover in Estonia is characterised by large territorial and temporal variations. The average duration of snow cover during winter is 75–135 days. Snow cover remains for the shortest time on the small islands near the western coast of Saaremaa Island and for the longest time on the Haanja and Pandivere Uplands.

As the Gulf of Finland is continental and with rather low salinity (2 ‰ - 6 ‰), its eastern part is covered by ice during some winter months. During warmer winters, there is no ice cover in northwestern Estonia.



The average air temperature in February and the annual average precipitation

ESTONIANS

Conversely, Estonia's population ranks amongst the smallest in the world: as of January 2000, an **estimated 1 361 242 people live in Estonia — a density of only 30.2 people per sq. km**. Approximately a third of the nation (398 434 people) live in Tallinn and about **67% of the population reside in cities** in general. The larger of these in descending order are: the university town of Tartu (101 140 inhabitants); the industrial border town of Narva (68 117); and the summer capital Pärnu (45 040) — the popular vacation destination on the southwestern coast, where summer air and water temperatures can reach those of the Mediterranean region.

Estonians belong to a small cultural group called "Finno-Ugric" which is made up primarily of Finns, Estonians, Hungarians. They have a language and ethnic identity completely different from Swedes or Germans in the west, and completely different from Russians in the east.

For the first 8,000 years, Estonians lived in peace. However, just because they were here first, did not mean that they would be respected. **For most of the last millennium, the Estonian people have been dominated by foreigners**. First it was the *Danish* in 1219, towards the end of the *Viking* era. They quickly sold this land to a group of *German* knights, the Livonian Order. Under German rule, Estonia prospered financially through increased trade. As *Sweden* rose to be a super power in the late 1500's, Estonia came under the Swedish Empire. The Swedish king started universities, schools, and generally improved the life of the Estonian people. But Sweden was the first to try to invade Russia in winter, and they, like Napolean and Hitler, lost. So then the *Russian czar* ruled Estonia from 1721 until 1918. Russia tried to push the Russian language, and the Orthodox church upon Estonians, in an attempt to "Russify" (make Russian) the population. In general, the condition of the Estonian people deteriorated under Russian rule.

On the 24th of February 1918 the **Estonian Republic** was proclaimed. At first this was merely a decision made on paper. Its period of independence was brief, however, and Estonia was forcibly annexed by the Soviet Union in 1940. But in 1991 Estonians again reasserted their independence, and peacefully broke away from the Soviet Union. So our second independence day is on the 20th of August.

Estonia became a **NATO member state** on 29 March 2004 and a **European Union member state** on 1 May 2004.

Estonians speak a soft, melodious language. Estonia is rich in folk songs. Estonians are poetically inclined, with lively imaginations and good memories. They are benevolent and of a friendly disposition (...), but certain vices, like flying into a rage, the desire for revenge and stubbornness, are not altogether alien to them (...).

Conversations-Lexicon, Brockhaus, 1877

Ernest Hemingway has written that in every port in the world, at least one Estonian can be found; this speaks volumes about the nation's enterprising spirit.

Throughout centuries, Estonians have always lived in the corner of the world where there is a large-scale migration of peoples. The Estonian language contains loan words from Low German, German, Swedish, Russian, French, Finnish and English. Those travelling through or those who have come here by chance, have doubtlessly left their mark on the Estonians' way of thinking and their character.

On the whole, not eager to display great joy or sadness, **Estonians are economical with their feelings.** Anyone coming from afar is struck by the cool demeanour and restrained reactions of Estonians. Although at official meetings people shake hands, privately, they avoid both handshakes and hugging; a friendly 'hello!' is a good enough substitute. It takes some time to penetrate their cool exterior. Those who have the patience to wait long enough find an easy-going conversation partner, a generous host and a faithful friend.

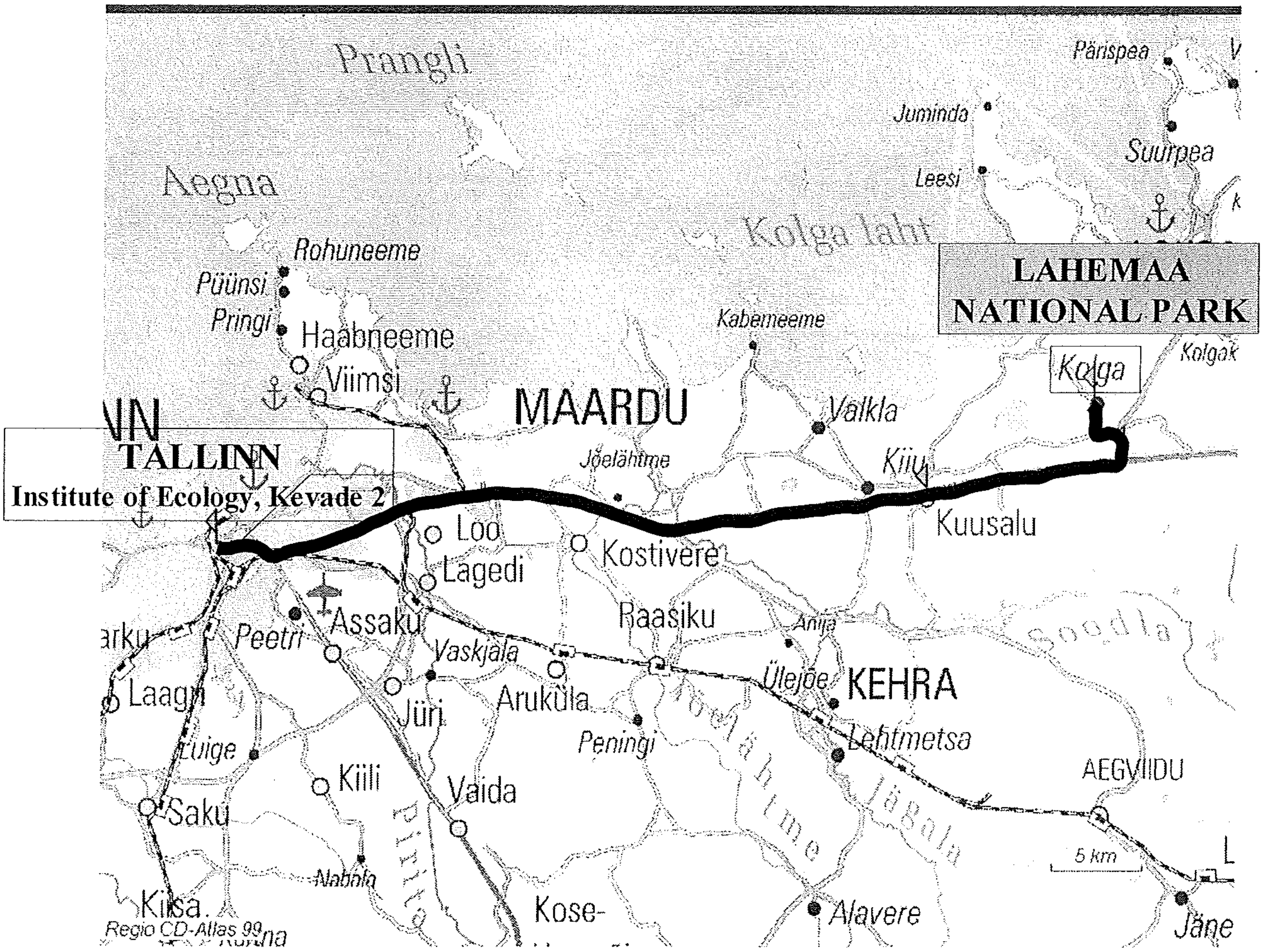
The only place one can see an Estonian roaring with laughter, is in a pub or in a sauna. Estonian jokes are for the most part cuttingly ironical and disguised. They are equally directed, without mercy, towards the jokers themselves, their neighbours and the government. Since relations between Estonians and all kind of authorities have always been complicated, an Estonian never trusts anyone merely because of their status. An Estonian is especially sceptical about people trying to teach him what and how he should go about his business. Consequently, he may seem overly headstrong at times. Stubbornness is a quality that an Estonian likes to include in the list of his positive qualities; Estonians associate it with their love of work and faithfulness to the place where they live.

Stoic Estonians

Saturday
21 August

Tallinn - Kostivere stone cist barrow - Raudsilla - Kolga

Saturday, 21.08.04



REBALA HERITAGE RESERVE

The plain landscape which opens for the travellers on the Tallinn-Narva road that passes through Jõelähtme, does not disclose itself easily. "Still waters run deep" as the saying goes. The dull limestone region acquires a totally different meaning when a passer-by learns that it is one of the oldest cultural lands extremely rich in various archaeological and historical antiquities and natural objects. On the North-Estonian limestone plateaus, the history of human colonisation can be traced back about 10 000 years. Most of the stone-age settlements were located close to the North-Estonian Klint and near the rivers, areas favourable for agriculture and fishing. Settlements on the Viru plateau are among the oldest in Estonia. The Mesolithic settlements near Kunda and Narva date from the 7000 B.C. The Kunda site gave its name to the archaeologically distinct Kunda culture.

Human activity has shaped the natural soils and plant cover of the North Estonian limestone plateaus. Primary small fields were replaced by larger fields during Neolithic slash-and-burn agriculture and more recently, by even larger, fertilised fields. From the Harju and Viru plateaus, colonisation moved slowly southward, and settlements were established on the Pandivere Upland. Open landscapes are characteristic of all the above mentioned regions. This landscape pattern has resulted from the interaction of man and nature, over the course of thousands of years.The rich historical heritage, which due to more than 5000 years of human settlement has been preserved up to the present day, now needs protection (Rebala Heritage Reserve). The North Estonian alvars should be considered the oldest agricultural region in Estonia where the first primitive slash-burn clearing of woods for the purpose of cultivation is known to have already taken place 2500 years ago. Within a mere 25 sq. km there are at least 3000 archaeological remains, making the area one of the densest archaeological sites in Estonia.

Rebala is one of the oldest villages of Estonia, and gave its name to ancient Rävala county and to Reval (the ancient name of Tallinn). The largest stone coffin graveyard in Estonia is in Muuksi, with 80 graves.

The burial places from late Bronze Age were founded between the 8th and 7th cent. BC. In the process of a new road construction archaeological rescue excavations took place from 1982 to 1984. During the excavations 36 stone cist barrows were found. The area was thoroughly excavated and the barrows were "lifted" beside the new road according to a photographed map. The dead had been buried in central coffins with their heads pointing to the north, facing the life-giving Sun. They were surrounded by a limestone wall, as if representing the world model of the man of that time - standing in the center of a circle, man could only look at the horizon, forever unattainable to him. There were few finds from the coffins. Objects like a bronze shaving knife and pincers put into coffins were most typical to Jutland toward the end of the Bronze Age. Evidently also the spindles found from the barrows originate from Danish territories. A unique boat-shaped stone coffin was found in the burial ground, too.

Sliding cultstone

In the middle of the grassland there is the largest ritual stone (height 3.5 m) with small hollows. Altogether there are about 100 such stones in the preservation area into which people have carved round hollows. The tradition of carving hollows dates from the 1st millennium BC and is connected to fertility and fecundity rituals. The sliding stone of Kostivere was believed to have had the power of granting fertility. The woman wishing to become pregnant had to slide down the stone on her bare bottom.

KOSTIVERE KARST FORMS

In the watersheds of the North-Estonian plateau, the rain water infiltrates through thin Quaternary cover and limestone pores and cracks. Striving for the springs and rivers, the water dissolves the surrounding rocks, forming underground **karst** channels. Smooth surface topography leads to the formation of channels in the uppermost bedrock strata or just below the Quaternary cover. When the ceilings of the channels collapse, the surface karst features — karst cones and dry valleys — are formed.

The karst channels have many levels. The lower levels are always filled with water, and the higher levels are flooded in high water. The water level in wells may vary by 10 or more metres. The connection between surface and underground water is marked by swallow holes, underground rivers (Kuivajõe, Jõelähtme) and numerous karst springs. There are perhaps more than a thousand karst cones up to 5–6 m deep as well as other surface karst features in Estonia. Three hundred and fifty-two surface karst features have been noted in the Pandivere Upland. The largest karst fields — Kostivere, Kata (Tuhala), Kuimetsa and Pae — are located in the Harju limestone plateau.

Other major karst fields are Savalduma in the Pandivere Upland and Uhaku in the Viru plateau. Among about 30 karst caves, the longest (54 m) was recently discovered in the Kata karst field. There are hundreds of large karst springs in Estonian limestone plateaus. The most numerous and water-rich springs (10 to 100 l/s and above) are on the slopes of the Pandivere Upland, from where the Pärnu, Jägala, Valgejõgi, Kunda, Avijõgi, Pedja and Põltsamaa rivers begin.

The Kostivere karst area, the largest in Estonia, is situated 21 km east of Tallinn. The development of the karst phenomenon is related to tectonical faults in Ordovician limestones. The upper part of the limestones and karst forms were destroyed during glacial erosion. The length of the karst area is 2,5 km and the Jõelähtme River flows here underground along a complicated system of karst hollows. The subterranean river has a number of branches, the two biggest of which are overlain by karst sink holes and sink basins up to 60 m in length and 4 m in depth, and a collapsed valley of about 300 m in length. There are also very interesting karst erosion forms – "stone tables" and "mushrooms". The subterranean Jõelähtme River emerges in the form of springs, which produce over 10 m^3 of water per second in spring.

Limestone – national stone of Estonia. The limestone strata have been studied in detail. Within the boundaries of the North-Estonian limestone plateau, the chronostratigraphic subdivision, based on fossil distribution, includes 16 Ordovician stages and three Silurian stages. Lithostratigraphic subdivisions include several formations and members. The main mineral resources of the Ordovician strata are oil shale and limestone. The limestone has been used for construction of castles, mansions, factories and smaller buildings, and for several buildings in Tallinn and Narva. It is also used as a raw material for cement in the Kunda cement factory. Earlier in history, local limestone strata were used for extracting lime by burning the limestone.

THE LAHEMAA NATIONAL PARK

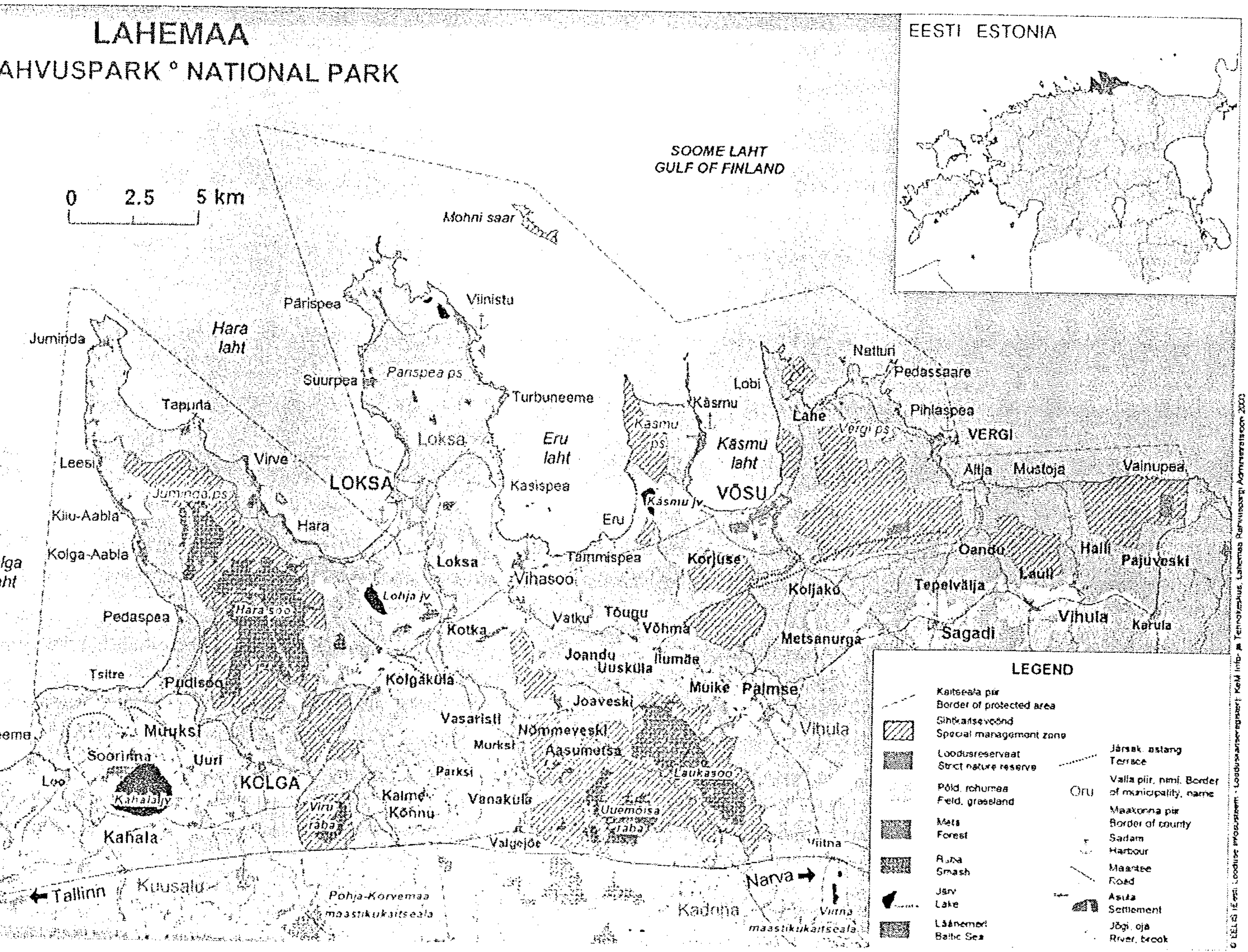
The park was created in 1971 to protect the characteristic North-Estonian landscapes and the national heritage of the area, and to preserve harmonious relations between man and nature. This was the first national park in the Soviet Union. Originally the area of the national park was about 440 km^2, but later the territory was expanded towards the south. Now its area extends over 725 km^2, 474 km^2 lies on land, 251 km^2 is the sea.

The Lahemaa National Park lies in the territory of two counties (Harjumaa and Lääne-Virumaa) and of four landscape regions (the North-Estonian Coastal Plain, the Harju Plateau, the Viru Plateau and Kõrvemaa). This territory was first called Lahemaa by Johannes Gabriel Granö in the early 20th century. The name originates from the most thoroughly studied part of the North-Estonian coast, where four large peninsulas (Juminda, Pärispea, Käsmu and Vergi) are separated from each other by four bays (Kolga, Hara, Eru and Käsmu.)

The present-day borders of the national park extend much farther than the original Lahemaa area, including a part of the Nort-Estonian limestone plateau and the northernmost area of Kõrvemaa. About 70% of the territory is covered with forests, with the coastal plain and Kõrvemaa being the most forested. Inhabitation is denser on limestone plateaus and on the coast. The Harju and Viru plateaus are the areas of the oldest permanently settled areas in Estonia and, thus, they are good examples of cultivated landscapes, clearly contrasting with those areas of the national park that are forested and rich in mires. A well-pronounced natural boundary between the plateaus and the coastal plain is the North-Estonian Klint, made more picturesque by several waterfall escarpments (Nõmmeveski on the Valgejõgi River, Joaveski on the Loobu River, and Vasaristi on the Vasaristi stream.)

Historically, almost all the coastal settlements were fishing villages, established, because of the poor conditions for agriculture in northern Estonia. Fishing and all the related activities, as well as the trade with Finnish coastal villages have traditionally been the main sources of income. Most of the large forests are protected and are not used commercially. Mineral water springs are located in Loksa and Viinistu, and small occurrences of natural gas have been found on Keri and Prangli Islands. The North-Estonian Coastal Plain is a perspective tourism and recreation area. The main resorts are Klooga, Laulasmaa, Vääna-Jõesuu, Rannamõisa, Kaberneeme and Salmistu near Tallinn and Võsu and Käsmu in Lahemaa.

Many former fishing villages, where owning boats and fishing was prohibited during the Soviet occupation, became resort villages; these include Altja, Vainupea, Karepa, Toolse, Kalvi, Aa, Toila, Oru and Voka. The most important resort since the end of the 19th Century has been Narva-Jõesuu



Sunday
22 August

Lahemaa National Park - Viitna lakes - Viru peatbog – Sagadi

Sunday, 22.08.04

THE VIRU BOG

One example of the North-Estonian mires can be viewed by walking on the nature trail (~3,5 km) trough the Viru bog.

The Viru bog is located in the southern part of Lahemaa National Park, ~50 km east from Tallinn. Its area is about 235 ha. Originally it was a small lake which formed behind the coastal dune of the Baltic ice-dammed lake. At the beginning of the Atlantic climatic period, approximately 6500 years ago, a fen was formed which later developed into a raised bog. The maximum thickness of peat is about 6 m (the average being 3,4 m), which is laying on 0,5-0,7 m of lake sediments (gyttja), sequencing with 0,5 m of fen peat and the uppermost part is bog peat.

The raised bog peat mainly contains very small amounts of mineral substances (less than 0,1 g l^{-1}), is acid (pH 4) and poor in bacteria. The raised bog is, figuratively speaking, a hillock of water because peat moss has the capacity to absorb great amounts of water. In the central part of the bog, watery and plantless patches are formed which turn into bog pools in the course of time. As the raised bog have a very poor supply of nutrients in their vegetation are dominated *Sphagnum* mosses. Among the stunted pines grows ledum (*Ledum palustre*) which contains essential oils and thus lends the distinctive scent to the whole bog. Among the ledum one can find knee – high dwarf birches and golden cloudberries.

At the beginning of the 20^{th} century the north-eastern part of the bog was drained and peasants hand-cut the peat. In the 1970s the excavation of milled peat was started. At present the peat cutting is stopped and some efforts are made to start the restoration of abandoned peat fields.

ALTJA

Altja is a typical coastal village, where the houses are built along the only street in the village. The only open-air geology museum in Estonia is also located near the village of Altja. Uustalu and Toomarahva as typical coastal farmsteads dating from the turn of the 19th- 20th century were restored by Lahemaa National Park. The other buildings of the village date back to the 1920-30s. The villagers have started using the old sheds for nets that were restored by the national park in 1973-1974 according to old photos and reminiscences of the villagers. In the water near the bay there is Suurkivi (Big Rock). Old stories tell that Altja babies came from behind the stone. In inland villages a crane was said to be bringing babies.

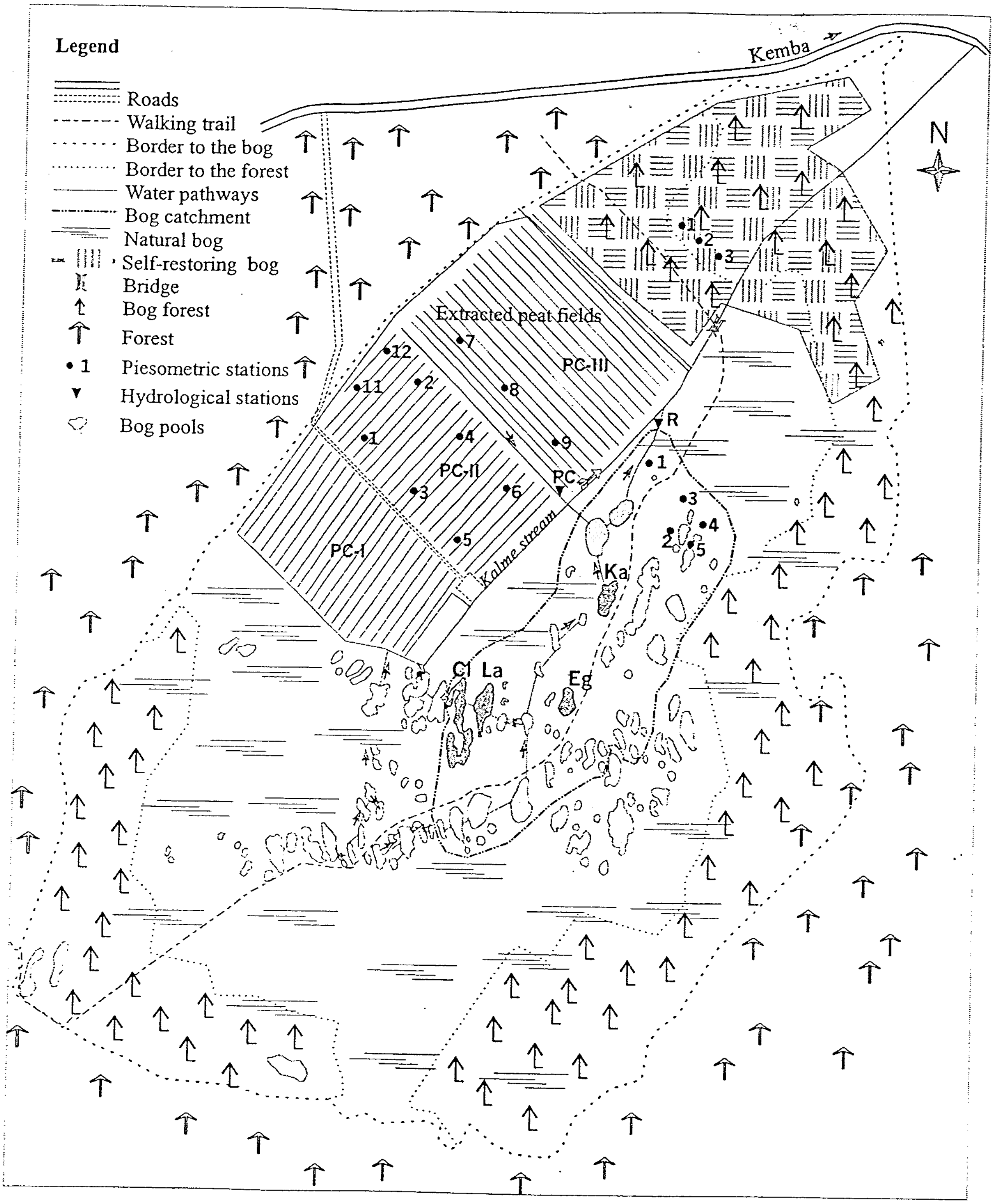


Figure Viru bog, Estonia

VIITNA PIKKJÄRV JA VIITNA LINAJÄRV

Hiking trail 2,5 km

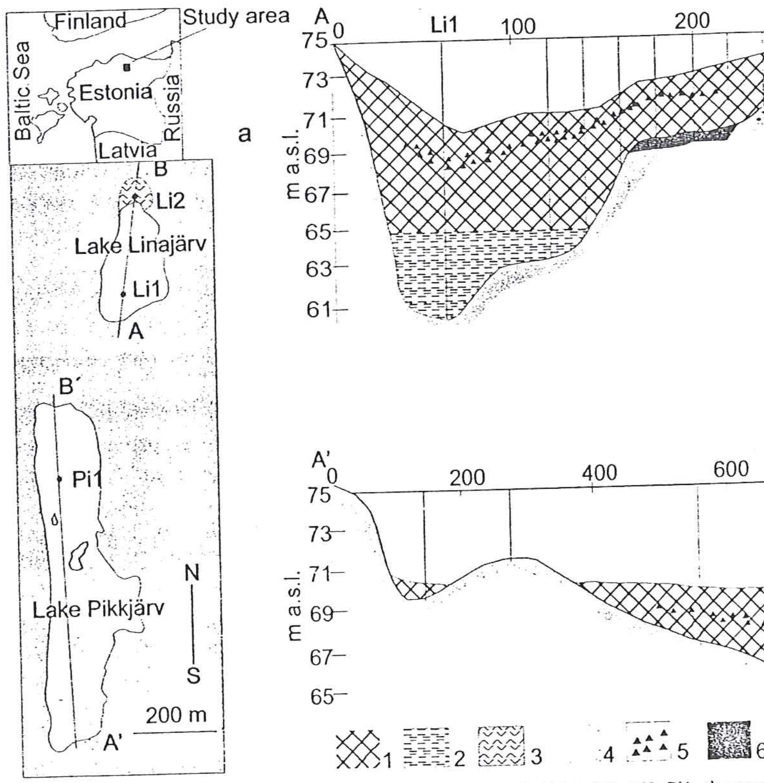


Figure 1. Study area and the lakes studied within Viitna Kame Field (a). Li1, Li2, Pi1- the core
through L. Linajärv (b) and L. Pikkjärv (c). Location of all cores used to compile cross-sections. Se
sediment; 3-peat; 4-sand; 5-plant remains; 6-clay; 7-moraine.

The main data of lakes Pikkjärv and Linajärv

Parameter	L. Pikkjärv	L.
Surface area, ha	14.8	3.8
Maximum water depth, m	6.0	4.8
Catchment area, ha	67	34
Maximum thickness of lake sediments, m	5.0	9.6
Altitude of contemporary lake-level, m a.s.l.	75	75
Altitude of basal lacustrine sediment layers, m a.s.l.	71	65
Age of basal lacustrine sediments, BP	9600	10

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Holocene lake-level changes and their reflection in the paleolimnological records of two lakes in northern Estonia

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Key words: Estonia, Lake-level fluctuation, Lake sediments, Lithology, Organic geochemistry, Vegetation history

Abstract

Sediment cores from two neighbouring lakes (Viitna Linajärv and Viitna Pikkjärv) in northern Estonia were studied to determine lake-level fluctuations during the Holocene and their impact on biogeochemical cycling. Organic matter and pollen records dated by radiocarbon and radiolead indicated a water level rise in both lakes during the early Holocene (c. 10 000–8000 BP). A regression followed around 7500 BP and several transgressions occurred during the latter half of the Holocene, c. 6500 and 3000 BP. Human impact during the last centuries has caused short-term lake-level fluctuations and accelerated sediment accumulation in the lakes. The differences in water depth led to variations in sediment formation. During 10 000–8000 BP (Preboreal and Boreal chronozones) mineral-rich sediments with coloured interlayers deposited in L. Linajärv. These sediments indicate intensive erosion from the catchment and oxygen-rich lake, which favoured precipitation of iron oxides and carbonates. Fluctuations in water depth, leaching of nutrients from catchment soils and climatic changes increased the trophy of L. Linajärv around 6000 BP. The subsequent accumulation of gyttja, the absence of $CaCO_3$ and the decrease in both the C/N ratio and phosphorus content in the sediments also indicate anoxic conditions in the hypolimnion. The similarity in the development of L. Linajärv and L. Pikkjärv and their proximity made it possible to discern the impact of water depths changes on biogeochemical cycling in lakes.

Introduction

Gaining insight into the development of lakes, their past conditions and future trends is pertinent not only for areas rich in lakes, but also on a wider scale, to assess the adaptation of environments to global processes such as global warming.

Information on past ecosystems gained through direct observation is often either unavailable or inadequate. The biological, geochemical and lithological information stored in lake deposits allows us to detect the changes in the depositional processes over millennia (Chambers 1993; Leavitt 1993; Hassan et al. 1997). If palaeoecological data can be correlated to specific events, cause-effect relationships can be established and the dynamics of landscapes and ecosystems can be modelled. These models may prove useful to predict the effect of future climate change (Punning and Koff 1996).

The study of matter fluxes in lakes is crucial for understanding the state and development of lake ecosystems. Changes in lake-level and lake water residence time, together with lake infilling, greatly influence biogeochemical conditions in lakes (Wetzel 1983; Cuddinngton and Leavitt 1999). Because sediment composition reflects the combined effect of hydrological and limnological processes, it is difficult to attribute a singular explanation in terms of water-level fluctuation.

The purpose of this research was to study the lithology, geochemical and paleobiological records of L. Viitna Linajärv sediments in order to establish changes in the lake-levels during the Holocene and to compare these with other regional data (Harrison and

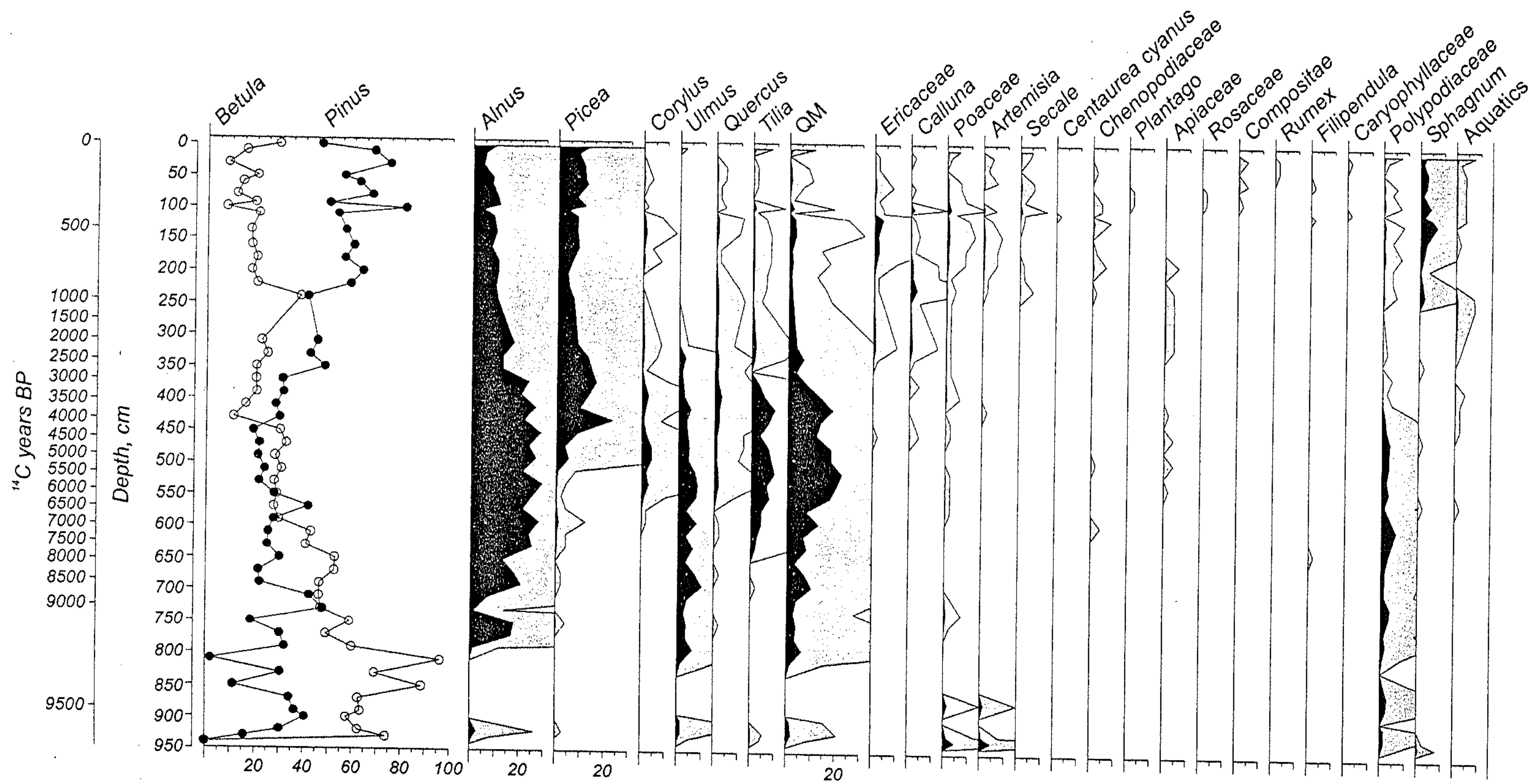

Figure 6. Percentages pollen diagram of selected taxa from core Li1.

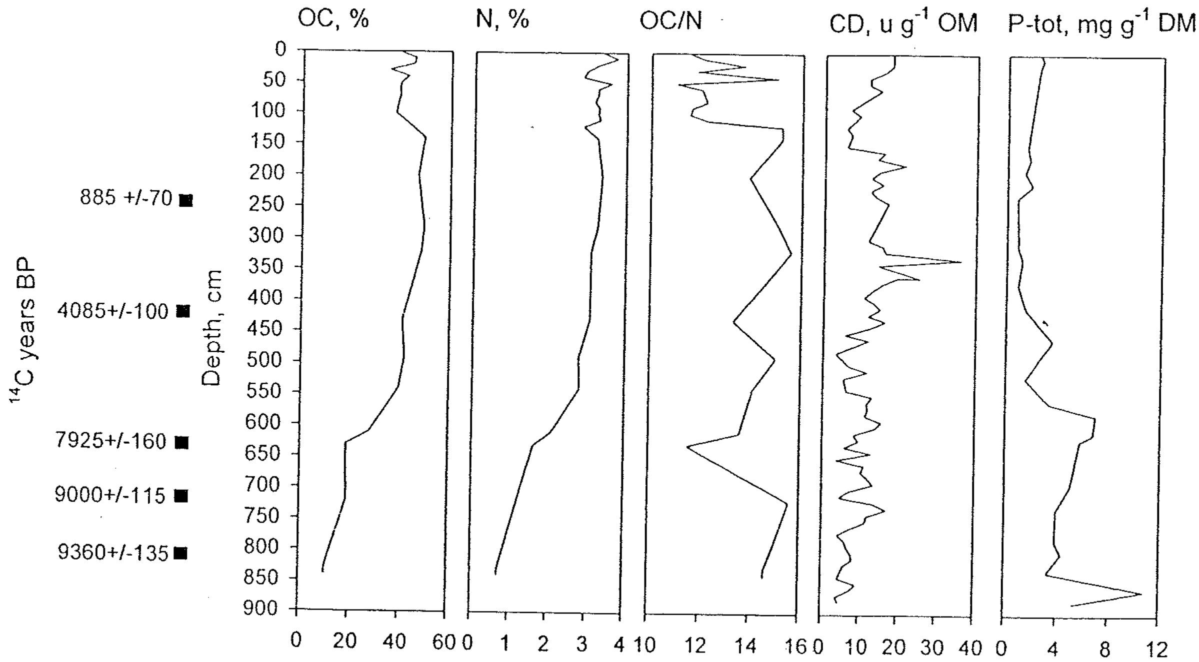

Figure 5. Geochemical and lithological composition of sediments in core Li1: organic carbon (OC) and N in % in dry matter and OC/N ratio, P-tot in mg g^{-1} dry sediments, sedimentary chlorophyll derivatives (CD) in organic matter in arbitrary units.

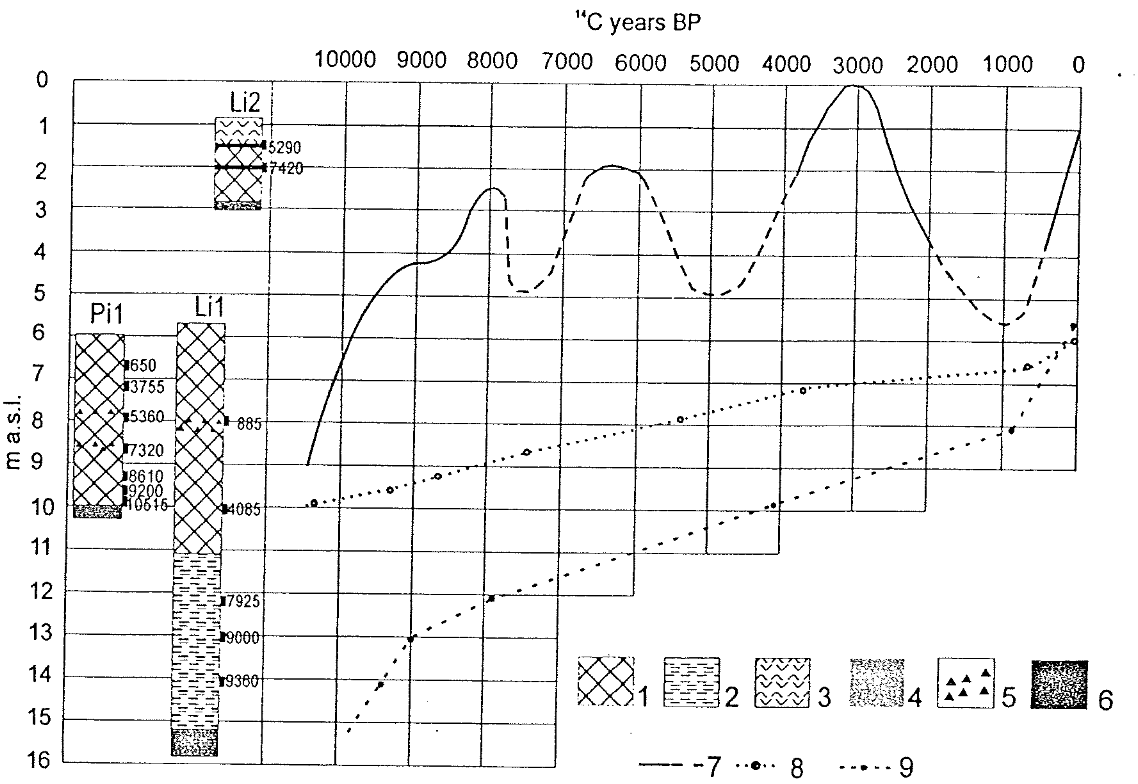

Figure 7. Development of Lakes Linajärv and Pikkjärv during the Holocene. Lithology and ^{14}C data for cores Pi1, Li2 and Li3 (note depth scales given in meters above sea level and dates expressed in uncalibrated ^{14}C years before present). Sediment description: 1-gyttja; 2-mineral-rich sediments; 3-peat; 4-sand; 5-plant remains; 6-charcoal layer; 7-reconstructed fluctuation of L. Linajärv level. Sediment limits: 8-L. Pikkjärv; 9-L. Linajärv.

Sofia - Moscow

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Aspects of Palynology and Palaeoecology
Festschrift in honour of Elissaveta Bozilova, pp. 113-126

Vegetation history in northern Estonia during the Holocene based on pollen diagrams from small kettlehole and lake sediments

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ABSTRACT

A small kettlehole and Lake Linajärv, two sites of different basin size lying close together, were used to study forest development in northern Estonia during the Holocene. Other sites from the same region were used for comparison. Good correlation between the studied sites and good correspondence with palaeoclimatic reconstructions for Northern Europe demonstrate that the main driving force of the vegetation development during the Holocene has been climate. On the local scale as shown by the pollen data from the kettlehole, the hydrological regime has also been of great importance.

KEY WORDS: Pollen analysis – Macrofossil analysis – Vegetation history – Holocene – Estonia

INTRODUCTION

The vegetation history in Estonia has been described on a broad scale since the late 1920s when P. Thomson, student of L. von Post, published his paper (Thomson 1929). Since then hundreds of pollen diagrams have been made by various researchers (Ilves and Mäemets 1987; Pirrus et al. 1987; Koff 1994, 1997; Veski 1998). Most of them are generally interpreted as a record of the vegetation of the region, on a scale of tens of kilometres. Theoretical and empirical results show that the source area of pollen is correlated with the size of the sediment basin (Jacobson and Bradshaw 1981). Sites can therefore be chosen to gain the desired level of spatial resolution in palaeoecological studies.

The challenge is to identify the regional pollen signal of the past and separate it from the local pollen inputs to reconstruct the local vegetation change of the past. Some attempts have been made also in Estonia by studying sediments from small mires to find the local peculiarities in the vegetation history depending on the role of the temporal distribution of radiation falling on deep kettleholes and differences in hydrological regime (Punning et

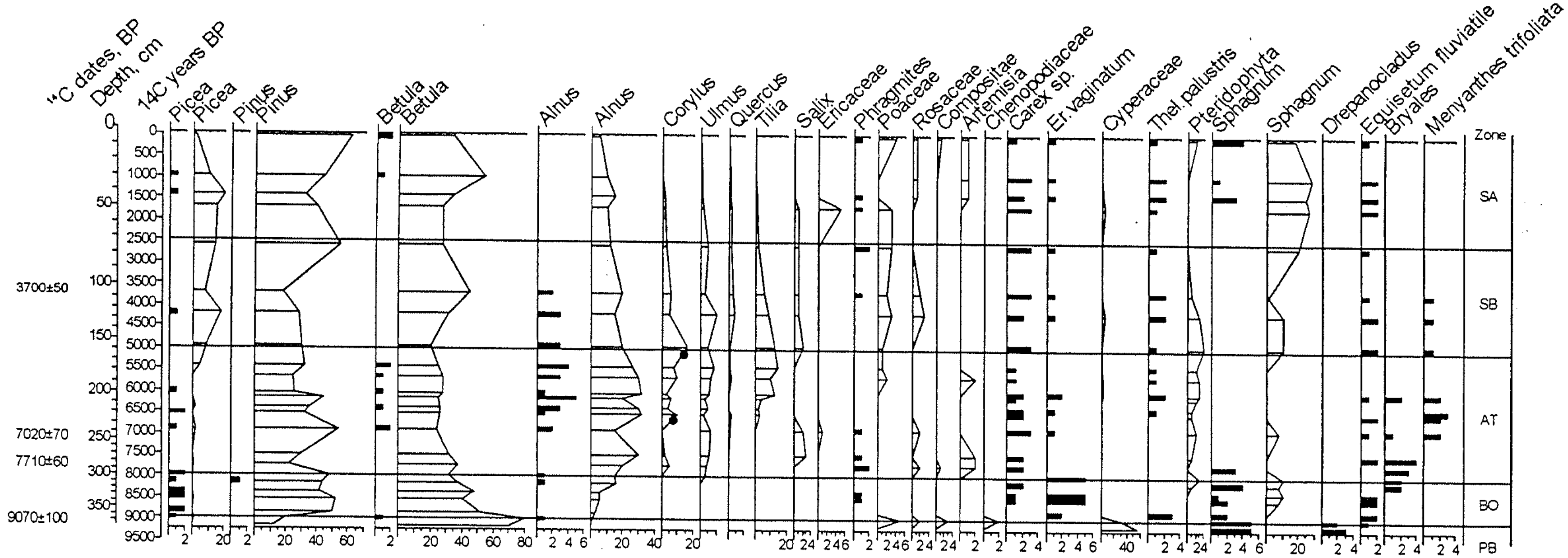

Fig. 3. Pollen and macrofossils diagram from small kettelhole (KH1). The results of macrofossil analysis are presented as solid bars in a relative scale of occurrence: 1 - rare; 2 - occasional; 3 - frequent; 4 - very frequent; 5 – abundant. Percentages of pollen data are based on the sum of arboreal pollen (AP) and terrestrial non-arboreal pollen (NAP). Zonation is given according to the stratigraphical scheme of the Holocene sediments in Estonia (Raukas et al. 1985). PB - Preboreal (10000–9000 BP); BO - Boreal (9000–8000 BP); AT - Atlantic (8000–5000 BP); SB - Subboreal (5000–2500 BP); SA - Subatlantic (2500–0 BP).

A COMPARISON OF SEDIMENT AND MONITORING DATA: IMPLICATIONS FOR PALEOMONITORING A SMALL LAKE

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Abstract. Long-term limnological monitoring data (from 1971 to 2001) were compared with sediment core record in Lake Viitna Linajärv (hereafter L. Viitna), a small lake in northern Estonia. The monitoring data show that L. Viitna changed from mesotrophic in the 1970s to eutrophic in the 1990s. The trends of paleodata that integrate the changes in the biogeochemical matter cycling in the lake over 2–3 years have clear signals about changes in the state of the ecosystem in L. Viitna during the last decades. A gradual increase in organic productivity should reflect a greater oxygen demand in the hypolimnion. As a result the hypolimnion became seasonally anoxic earlier and its pH level remained low for a longer time. These fundamental changes near the sediment-water interface were recorded in the sediment core. The greatest changes occurred at the beginning of the 1980s (layers at a depth of ca. 20 cm), when the meso(eu?)trophic conditions in L. Viitna started to become increasingly more eutrophic. The variations of paleorecords in the upper part of the sediment core coincide temporally with changes in the water level of the lake.

Keywords: fossil pigments, lake monitoring, lake sediments, lake trophy, paleomonitoring, phosphorus cycling

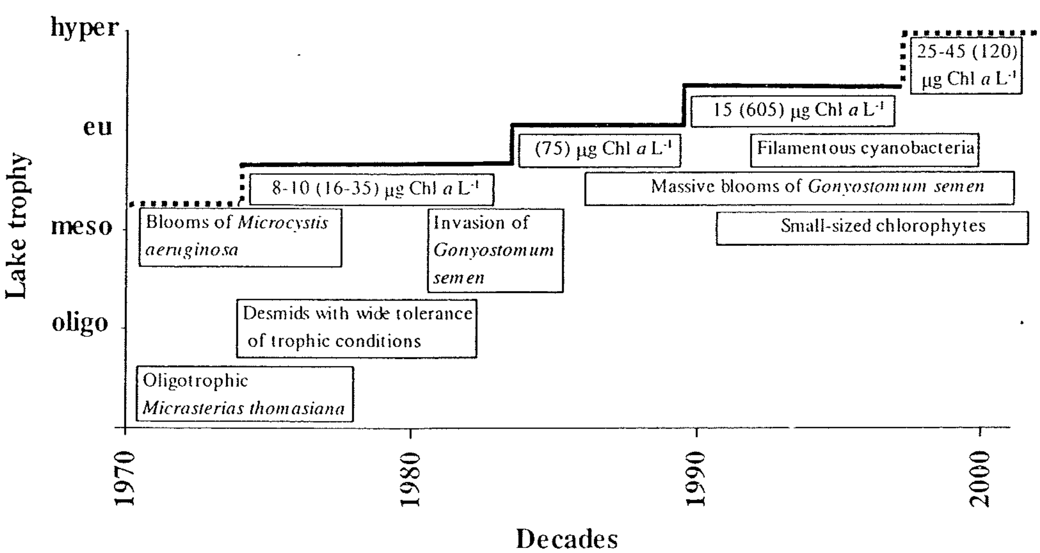

Figure 4. Changes in chlorophyll *a* (Chl *a*) concentration (maxima in parenthesis) and alterations in the composition of the phytoplankton community indicating the rise in the trophy of Lake Viitna. For details see the Results Section.

Hydrobiologia 00: 1–11, 2004.

Recent patterns of sediment accumulation in a small closed eutrophic lake revealed by the sediment records

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Key words: lake sediments, lake-level fluctuations, core studies, mineral and organic matter, palaeolimnology

Abstract

A short-core palaeolimnological investigation was undertaken with the aim of acquiring knowledge of sediment deposition. Analyses of the lithological composition of sediments from the whole-lake basin were performed on the small eutrophic L. Linajärv (northern Estonia) and the concentrations of mineral and organic matter were measured on 647 sub-samples from 14 sediment cores. The accumulation rate of the sediment sequences was established and C/N ratios of organic matter in some cores were recorded. Results indicate that the water depth, basin slopes and distance to the shore have the most important impact on the physical sediment properties. It was shown that variations in the mineral matter concentrations were influenced by the changes in deposition conditions in the areas with steep slopes. The study indicated that more objective information about the sedimentation mechanisms is obtained using analysis of the concentration ratio of mineral and organic matter since it reduces the implied role of diagenetic compaction.

Introduction

In order to interpret a sedimentary record for reconstruction of natural and human induced impacts and compile a matter flow budget in a lake, the processes in the water column and at the sediment-water interface have to be well understood. The results of phosphorus cycling, thoroughly studied during several decades (see Boström et al., 1982), demonstrate that the sedimentation regime plays a fundamental role in matter cycling, governing the energy flow through an aquatic ecosystem.

Investigations of spatio-temporal variations in sediment accumulation rate and composition of sediments have received special attention (Davis & Ford, 1982; Dearing, 1983, 1997; Davis et al., 1985; Verschuren, 1999; Yang et al., 2002). The shape and volume of the lake, the allochthonous sediment discharge, the autochthonous production, the sediment characteristics, turbidity currents, resuspension, hydrodynamic flow patterns, lake level changes etc must be taken into consideration in order to determine the accumulation of sediments. As these factors have impact on the sedimentary signal, the selection of coring site for paleolimnological purposes often plays crucial role in the research strategy (Dearing, 1983; Mudroch & Azcue, 1995).

According to the traditional model of sediment focusing, higher accumulation and the highest inventories are expected in deeper water (Lehman, 1975; Likens & Davis, 1975). However sedimentation in lakes is complex in nature and a generally accepted concept of sediment focusing is not always observed (Yang et al., 2002). Many studies have demonstrated the importance of lake morphometry on sedimentation as well as on resuspension (Håkanson & Jansson, 1983; Blais & Kalff, 1995; Weyhenmeyer et al., 1997). As the topography of the lake basin can be quite variable, different morphometrical parameters determine sediment accumulation or erosion. Therefore, the whole-lake deposition pattern may be extremely patchy and temporal variability can be evident.

Sedimentation patterns can change through time for a variety of reasons, one being changes in lake-level (Verschuren, 1999). Sediment studies have been successful in investigating lake-level variations in small temperate lakes (Digerfeldt, 1986; Dearing, 1997). The fluctuations of water level alter the lake morphometry and transform the characteristics of the sedimentation zones (erosion, transportation, accumulation; Håkanson, 1977) of the lake bed, thereby directly influencing sedimentation and resuspension. This may change properties of sediments accumulating in the lake, e.g. their mineral matter content, grain size distribution and will lead to increasing rates of mineral matter delivery (Shteinman & Parparov, 1997). The fluctuations of lake level can also cause changes in aquatic vegetation assemblages and may shift macrophyte zones. A recent study of Tarras-Wahlberg et al. (2002) shows that water level fluctuations have significant effect upon sediment characteristics and changes in aquatic vegetation assemblages. Madsen et al. (2001) demonstrate that water movement affects sediment dynamics in and around submersed macrophyte beds, its composition and particle size in freshwater environment.

The purpose of this short-core palaeolimnological investigation was to study recent sediment deposition in the small eutrophic Lake Viitna Linajärv (hereafter L. Linajärv) in relation to basin morphometry parameters (water depth, underwater slopes), and to describe the patterns of sediment composition and its temporal dynamics of the whole lake basin.

Material and methods

Limnological setting

The study was carried out in Lake Linajärv, situated in northern Estonia (59°27′N, 25°01′E) (Fig. 1). Limno- and fluvioglacial sediments cha-

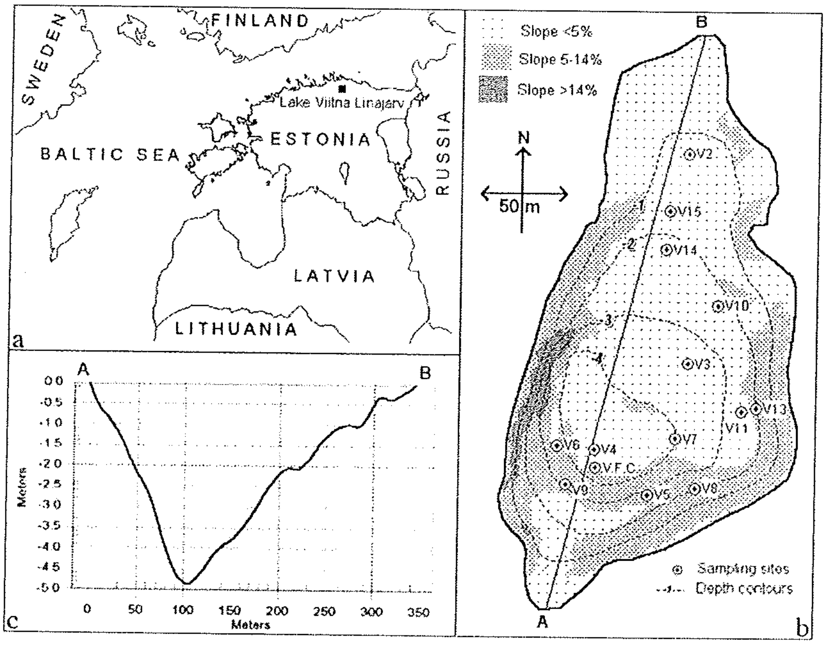

Figure 1. The location (a), morphometry parameters and sampling sites of Lake Linajärv (b). Shaded areas denote basin regions with different underwater slopes; A and B shows the depth profile (b, c).

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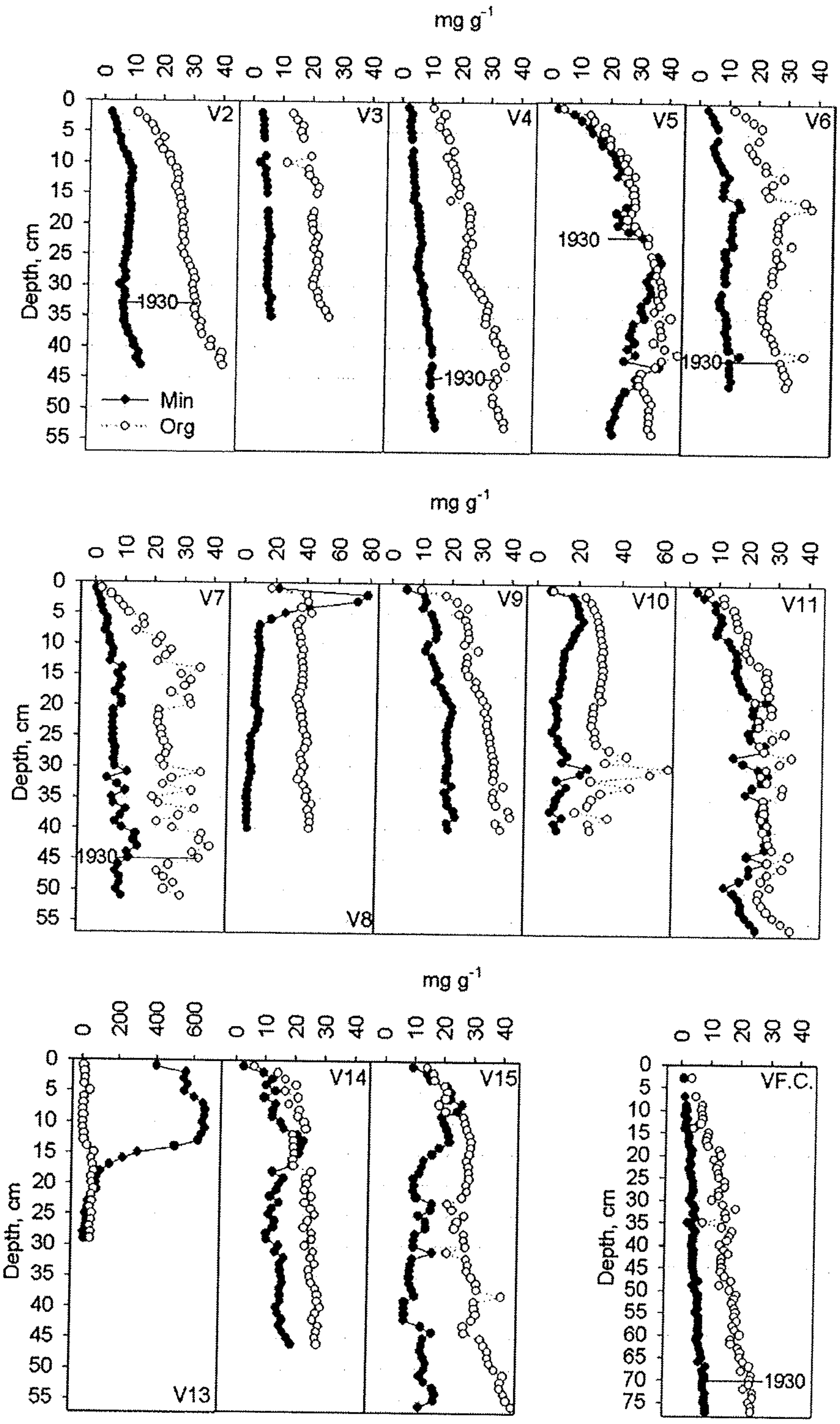

Figure 2. Changes of the concentrations (mg g^{-1}) of mineral and organic matter in the different cores. Year 1930 is the reference level where the increase in spheroidal fly-ash particle concentration profile was detected (see Fig. 5).

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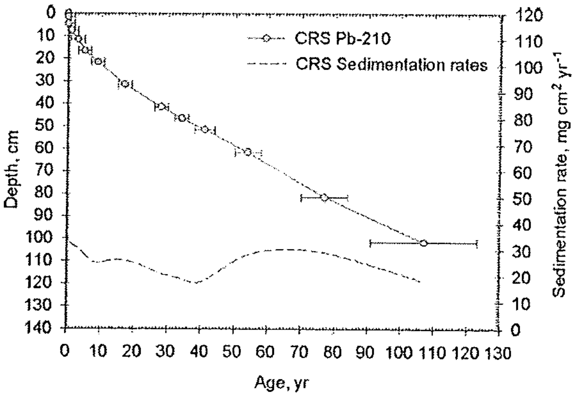

Figure 4. The age-depth curve and sedimentation rate in core VF.C. of L. Linajärv obtained by CRS ^{210}Pb dating model. Error bars of age-depth curve represent standard error in calculated age caused by the measuring accuracy of the ^{210}Pb activity.

the lake (cores VF.C, V4, V6 and V7), where the water depth was more than 3 m and slope inclinations of the lake basin were small. In the shallow and macrophyte-rich northern area of the lake (core V2) we recorded 30% lower sediment accumulation rate than in the deepest part of the basin showing there weaker effect of sediment focusing. Steeper underwater slopes causing erosion and transportation of sediments, can explain the lower mean accumulation rate and higher relative content of mineral matter in core V5.

It has been widely recognised that sediments are not distributed evenly over the bed of most lakes. Yang et al. (2002) found that along individual transects, there is a good relationship between sediment thickness and the water depth inside the sediment limit area in the oligotrophic Lake Lochnagar, but the relationship was not strong for all cores in the lake basin.

Obtained data allowed us to examine recently formed sedimentation patterns in L. Linajärv in relation to basin morphometry parameters. As the variability in concentrations of mineral and organic matter with sediment depth indicates temporal changes in deposition conditions, they vary from place to place and depend on the circumstances at the coring site. Our results suggested strong links between the temporal changes in sediment composition in single cores and lake bottom topography. In cores taken from deeper water, or areas with moderate underwater slopes, concentrations of both organic and mineral matter

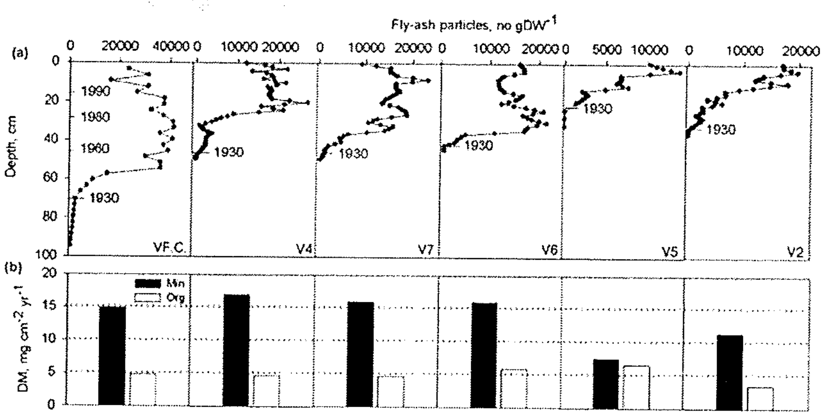

Figure 5. Distribution profiles of spheroidal fly-ash particles in master core (VF.C.) dated by ^{210}Pb method and in cores V4, V7, V6, V5, V2 indirectly dated by reference level (year 1930) where particle concentration starts to increase (a). Calculated average annual accumulation of organic and mineral matter in different cores since 1930 (b).

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C/N RATIO AND FOSSIL PIGMENTS IN SEDIMENTS OF SOME ESTONIAN LAKES: AN EVIDENCE OF HUMAN IMPACT AND HOLOCENE ENVIRONMENTAL CHANGE

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Abstract. The content of carbon (C), nitrogen (N), fossil carotenoids (TC) and chlorophyll derivatives (CD) in the sediments of five Estonian lakes was analysed. Historical records of man-induced changes on catchments were used for the interpretation of the obtained data. On the basis of the C/N ratios it was estimated that the planktonic matter formed ca. 25% (C/N ratio 24) to 90% (C/N ratio 8) of the organic pool matter of lake sediments. In eutrophic Lake Ruusmäe the fraction of the phytoplankton produced in lakes was highest, amounting to approximately 80–95% of the deposited organic matter. Remarkable C/N changes were noted in the sediments from lakes Matsimäe and Viitna, where the content of planktonic matter has increased during last decades, reflecting an increase in recreational activity around these lakes. The variations in pigment concentrations in the sediments of lakes Matsimäe and Ruusmäe could be explained by changes in the land-use that have altered the intensity of primary production and conditions of TC and CD degradation before the final burial.

Keywords: carbon and nitrogen in sediments, fossil pigment production and destruction, human impact, lake sediments, palaeomonitoring

1. Introduction

The essence and intensity of the factors and processes influencing the lake ecosystem, and their consequences are extremely complicated, which causes high temporal and spatial variability in the chemical and biological characteristics of water masses in lakes. Thus, it is very rarely possible to reconstruct the correct state of past ecosystems on the basis of short-term monitoring data. Palaeorecords in lake sediments can be used for monitoring long-term changes in land-use. The biological, geochemical and lithological information stored in accumulative deposits makes it possible to follow the changes in the processes, affecting sediment deposition over certain time periods (Chambers, 1993; Leavitt, 1993; Hassan *et al.*, 1997; Lami *et al.*, 1997). Data of this kind are also needed to establish the sensitivity of ecosystems, and, thus, create a scientific basis for the introduction of necessary mitigation measures (Eriksson, 1996).

During the last 4–5 decades the land-use intensity, agricultural and industrial load on the environment has increased drastically in Estonia. As a result, the rela-

Environmental Monitoring and Assessment 64: 549–567, 2000.

THE TRAPPING OF FLY-ASH PARTICLES IN THE SURFACE LAYERS OF *SPHAGNUM*-DOMINATED PEAT

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(Received 11 April, 1995; accepted 5 December, 1995)

Abstract. The movement of fly-ash particles in a sequence of *Sphagnum* moss was studied in laboratory experiments and field investigations. The data obtained in the laboratory show that only 0.8% of particles, placed on the surface of a 6–10 cm thick *Sphagnum* layer, were washed out with water (700–750 mm) during the 241 days of the experiment. The majority of added particles were fixed in the upper part (90% in 1–3 cm) of the moss layer. A SEM study indicates that sorption is slightly species-dependent due to the micromorphological parameters of the *Sphagnum* species. The storage of particles by *Sphagnum* mosses allows the use of natural sequences to study the history of atmospheric pollution. The distribution of particles in the upper part of moss layers in Viru Bog (50 km east of Tallinn, North Estonia) shows good agreement with the known air pollution history in Tallinn.

Key words: fly-ash particles, ombrotrophic peats, air pollution history, monitoring

1. Introduction

During the last decade particles produced by fuel combustion have been used to study the temporal and spatial distribution of man-made pollutants deposited from the atmosphere (Goldberg *et al.*, 1981; Wik and Renberg, 1991; Rose *et al.*, 1994). Spheroidal carbonaceous and inorganic particles are mainly derived from high temperature combustion of fossil fuels and their morphological features, quantity and chemical composition are determined by the type of fuel and combustion regime (Rose *et al.*, 1994; Wik, 1992). Therefore the particles serve as good tracers for the atmospheric dispersion of pollutants.

Coarse spheroidal carbonaceous particles are chemically resistant even with strong oxidants like hydrogen peroxide (H_2O_2) (Renberg and Wik, 1985) and acids such as hydrofluoric acid (HF), nitric acid (HNO_3) and hydrochloric acid (HCl) (Rose, 1990). Empirical data demonstrate that high temperature combustion particles retrieved from marine sediments, soils and lake deposits have well preserved features (Wik, 1992). This makes them a good tool for historical monitoring and paleoecological study.

The most widely used sources for paleoecological investigations are lake sediments and peat sequences. In principal, the most faithfully recorded information on past atmospheric processes might be obtained by studing ombrotrophic peat sequences. The main advantages of ombrotrophic peats are that they obtain mineral matter directly from atmosphere, have a lack of post-sedimentational mechanical disturbances, have a relatively rapid annual increment and the better possibilities

Figure 4. Fly-ash particles on the surface and in the pores of *Sphagnum angustifolium*. Bar is 5 μm.

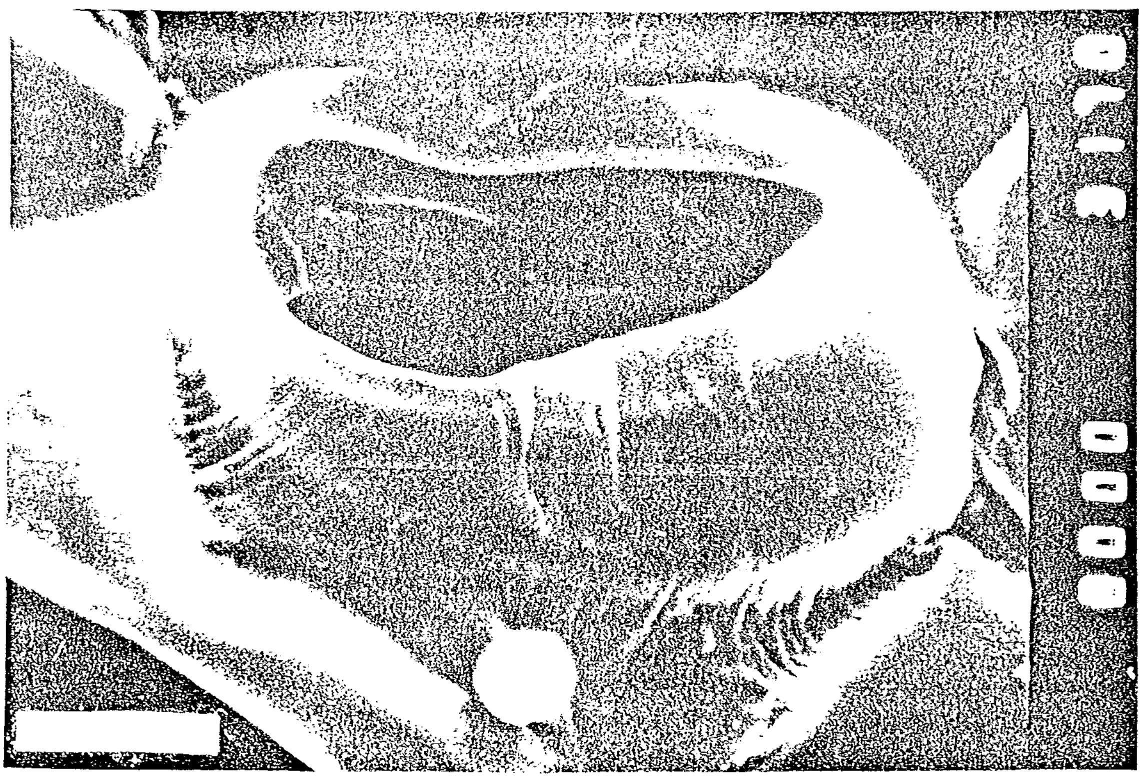
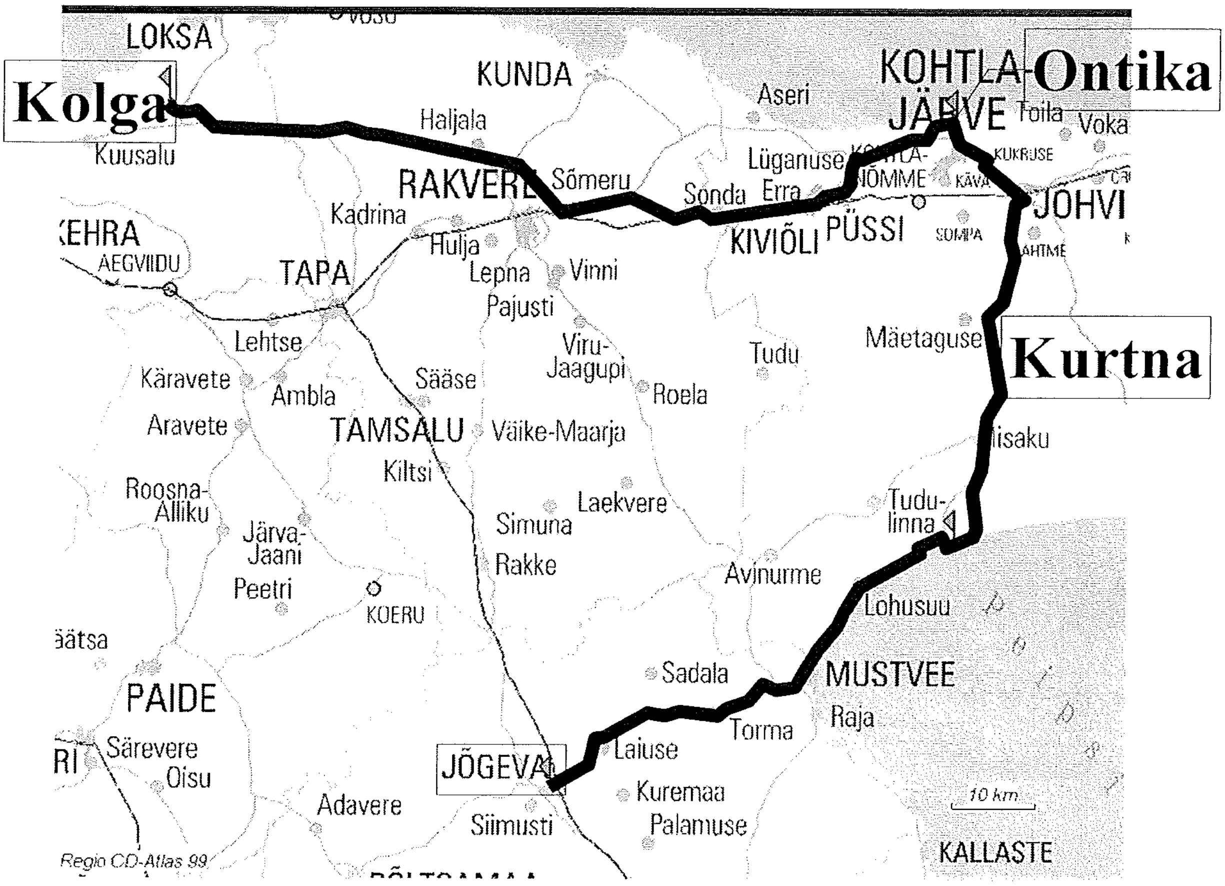


Figure 5. Fly-ash particle trapped on the surface of *Sphagnum magellanicum*. Bar is 5 μm.

Monday
23 August

Ontika - Kurtna lake district - Lake Peipsi

Monday, 23.08.04



ONTIKA

The first recorded marks about Ontika village are from "Taani hindamisraamat", where Ontika village is mentioned under the name of Underaegase. Ontika Manor appeared in cronicles in the middle of the 17th century, the owner was Anthoni Falkenklau. Now there is a guest house in the manor, it is possible to organise seminars there.

Then we go on for a long time on the limestone plateau known as the Glint which is at its highest between Ontika and Valaste (56 meters). From the platform at **Valaste Waterfall** (the highest in Estonia, 25 meters) you can see the crosscut of the Glint.

NORTHEASTERN ESTONIA

Landscape of northeastern Estonia probably most vividly reflects the footprints of modern industrial activity of the man. View of a boring flatland is enriched here by many hills with historical background - ten thousand years old glacier formations together with monumental hills of ash and limestone-leftover from twentieth century.

The beauty of North-East lies in balance and conflicts. One can see fields covered with limestone, crippled machines, no-ones land and beautiful forests but with high tips of ash hills begins the noteworthy scenery. From the top of ash hill in Kiviõli, which is 115 meters from the ground, the eye reaches very distant places. In the North there's a blue sea, in the South there's forest, in the East lies industrial silhouette with chimneys, power lines and man-made hills of different height.

The most important among the natural resources of the area is **oil shale**. The dark side of oil shale mining is its damage to nature. The mining and benefication of oil shale and its use in the energy and chemical industry have damaged the Earth's structure, landscape, surface and ground water, atmosphere, plant cover and animal life, and human health and living conditions. The area, damaged or strongly influenced by mining, exceeds 300 square km, and is continuously growing. Industrial outlets influence neighbouring areas and water bodies: Lake Peipsi, the Narva River and the Gulf of Finland. Solid waste hills are distinct landscape features in Northeast Estonia.

Although underground mining does not damage the Earth's surface rapidly, its long-term impact restricts land use and human activities in the mined areas. Underground mining of oil shale has resulted in change in the water regime; low wells have become dry and soils in forests and fields have lost moisture. Mining and pyrite oxidation have polluted the water in old mines, and this pollution has reached ground water reservoirs. The ceilings of the shafts located at a depth of 10–50 m keep collapsing, leaving the Earth´s surface with terraces and holes. The former mining areas are not suitable for building construction.

The influence of the open cast mining is more directly perceivable. Natural landscapes, soil cover, plant cover, and surface waters have been destroyed, other mineral resources (e.g. sand and peat) have been damaged. Also, several old villages have perished. Instead, new artificial landscapes are formed that consist usually of plateaus and networks of channels that fill with the water later on.

Numerous mines have been closed down during Soviet times and forest has slowly started to grow back either by itself or with the help of man. Pine, birch and larch trees have been used for reforestation of new landscapes, formed after the reclamation of old pits. Decades later, lichens and mosses, grasses and bushes have not yet recovered in these forests, but wild animals have returned to the area. Bears have been encountered in forested, uneven landscapes of the Viivikonna Quarry, which are nearly inaccessible.

The development of the oil shale industry has lead to active use of other mineral resources. From some bogs, peat has been used for manufacturing peat briquettes, litter and fertiliser. The largest peat-milling field in Estonia is located at Oru. It was created in order to extract the peat before mining oil shale in the Viivikonna and Sirgala open pits. Large quantities of gravel and sand have been used for construction of roads and buildings. To a lesser extent, limestone and clay have been used, and, until the late 1980s, so was Dictyonema Shale. Long-time production of uranium and rare earth metals in Sillamäe from imported raw material has left environmentally hazardous waste.

Near Kunda, the industrial area includes a cement factory and limestone and clay pits. For decades, the cement factory has been polluting the town and its surroundings with lime dust. The recent installation of new dust filters has led to a decrease in pollution. Mining of gravel and sand has reshaped the landscape as well.

IMPACT OF INCREASED ATMOSPHERIC INPUT ON OMBROTROPHIC MIRES IN NORTHEAST ESTONIA

By Edgar Karofeld (Institute of Ecology)

Northeast Estonia is one of the most paludified counties in Estonia (mires cover *ca* 38 % of the territory) including our biggest - Puhatu mire system (initially *ca* 57 thousand hectares decreased by open-pit oil-shale mines in northern part down to *ca* 36 thousand hectares), Muraka and Sirtsi bog and numerous others. But beside mires, Estonian heavy industry - oil-shale mining and processing is also concentrated in North East *ca* 80 % of annually produced oil-shale (around 10 million t) is used to burn in electric power stations. Due to the pure environment protection measures during the Soviet time electric power stations emitted to the atmosphere annually up to 400 thousand tons of Ca-rich strongly alkaline (pH~ 12) oil-shale fly-ash. When sedimenting to the ground, including mires, fly ash have caused essential changes in soil and surface waters pH and nutrients regime. Caused by heavy atmospheric load in NorthEast unusual situation formed. Mires, which are still ombrotrophic - feed solely by the precipitation are not oligotrophic or nutrient poor any more.

Changes in air-polluted bogs are studied in more detail in Niinsaare and Liivjärve bogs where mostly because of the combination of increased pH (from natural ca 3.7 up to 5-6) and Ca concentration in bog water *Sphagnum* mosses almost disappeared from these mires. The number of vascular plant species is increased more than 4 times and includes species typical for Ca rich habitats (*Epipactis palustris, Festuca rubra, Lonicera baltica* etc). However, after the decreasing of oil-shale ash emission essentially positive changes started on these mires - Sphagnum patches appeared and increase their area. This give the hope that essentially changed mires could still recover and restore their natural look.

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The effects of alkaline fly ash precipitation on the *Sphagnum* mosses in Niinsaare bog, NE Estonia

Emäksisen tuhkalaskeuman vaikutus rahkasammaliin Niinsaarensuolla Koillis-Virossa

Edgar Karofeld

Edgar Karofeld, Institute of Ecology, Kevade Str. 2, EE-0001 Tallinn, Estonia (e-mail eco@eco.edu.ee)

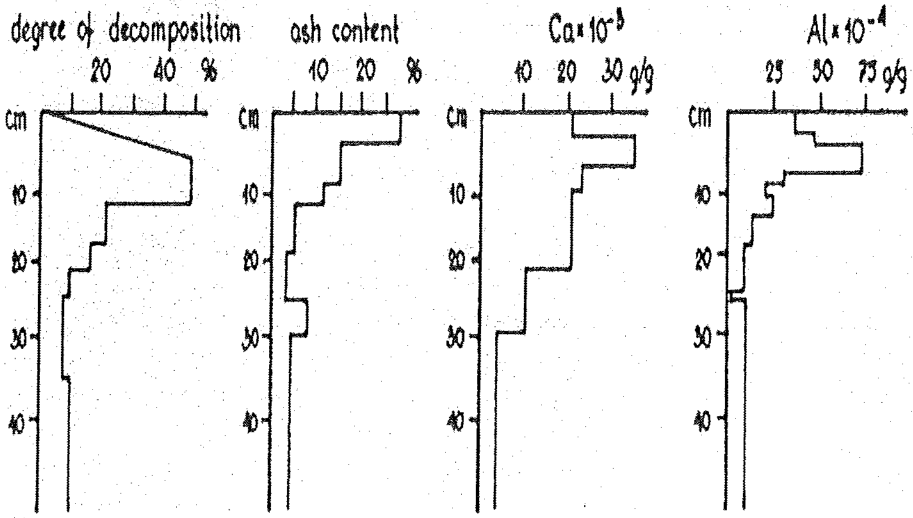
In north-east Estonia, the precipitation of calcium-rich strongly alkaline fly ash from thermal power stations has caused significant changes in the local ombrotrophic mires. *Sphagnum* mosses disappeared from Niinsaare bog during the 1970s in the period of the highest air pollution. Their disappearance was probably caused mainly by the combination of high pH values and an increased concentration of calcium in the bog water. In Niinsaare bog, the present mean pH value of bog water is 5.3 ± 0.6 and the mean calcium concentration 11.6 ± 1.6 mg l^{-1}, compared with 3.7 ± 0.4 and 1.9 ± 0.2 mg l^{-1} in the uncontaminated Nigula bog respectively. During the last decade, following the reduction of fly ash emission, the *Sphagnum* mosses started to reappear in Niinsaare bog. Nine *Sphagnum* patches dominated mainly by *S. angustifolium, S. fallax and S. magellanicum* were studied from June 1991 to September 1995. During one year, the distance between the centre and edges of these patches increased on an average by 5.1 ± 2.7 cm and the area by 29 ± 21.5%. This indicates that the degeneration of *Sphagna* in NE Estonian bogs is not yet irreversible and, by reducing the air pollution in the long term, the restoration of *Sphagnum* carpet is possible.

Key words: atmospheric pollution, degeneration and recurrence of *Sphagna*, ombrotrophic mire

INTRODUCTION

The disappearance of *Sphagnum* mosses from bogs in industrial areas started ca. 150 years ago (Tallis 1964, Adams & Preston 1992) and still continues. There are several studies during the last decades from North America (Gorham et al. 1984, Gignac & Becket 1986, Austin & Wieder 1987) and West Europe (Tallis 1973, Smith 1978, Woodin et al. 1987, etc.) dealing with the effects of air pollution on bogs and *Sphagnum* mosses (Ferguson & Lee 1978–1980, Ferguson et al. 1978, Press et al. 1986, Bayley et al. 1987, Aerts et al. 1992). In these papers, the degradation of *Sphagnum* is explained mainly by the high SO_2 concentration in the air and high sulphur input. The ombrotrophic mires and *Sphagna* are especially sensitive to air pollution since they receive all their nutrients from the atmosphere.

Starting times of electric power stations (Ahtme 1951/55, Balti 1959, Eesti 1969) reflects as increased ash content, Ca, Al etc concentration in the uppermost peat layer and tree rings width in nearby Niinsaare and other bogs. The content of Sb increased *ca* 1800 and that of Cs by >2100 times as compared to the period before the oil-shale industry started.



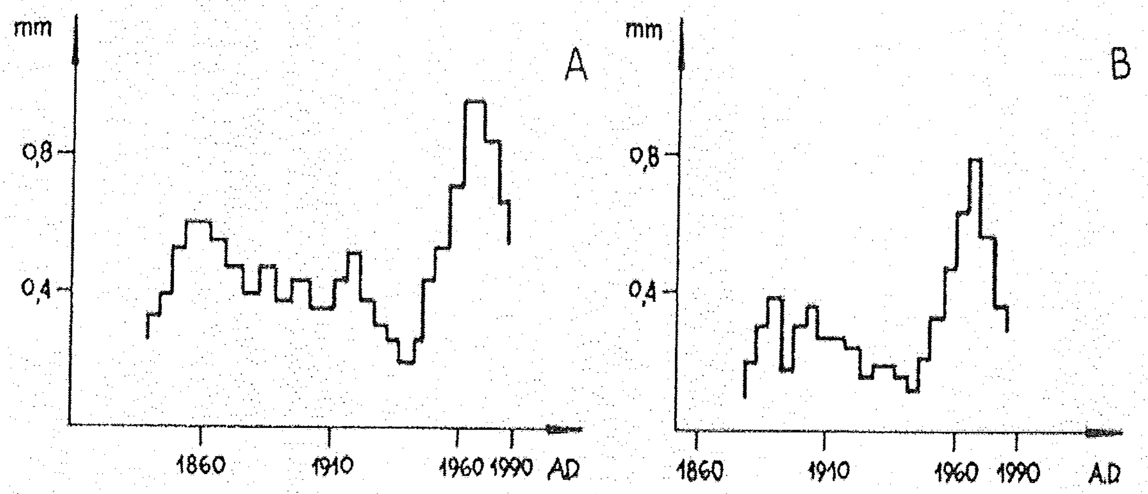
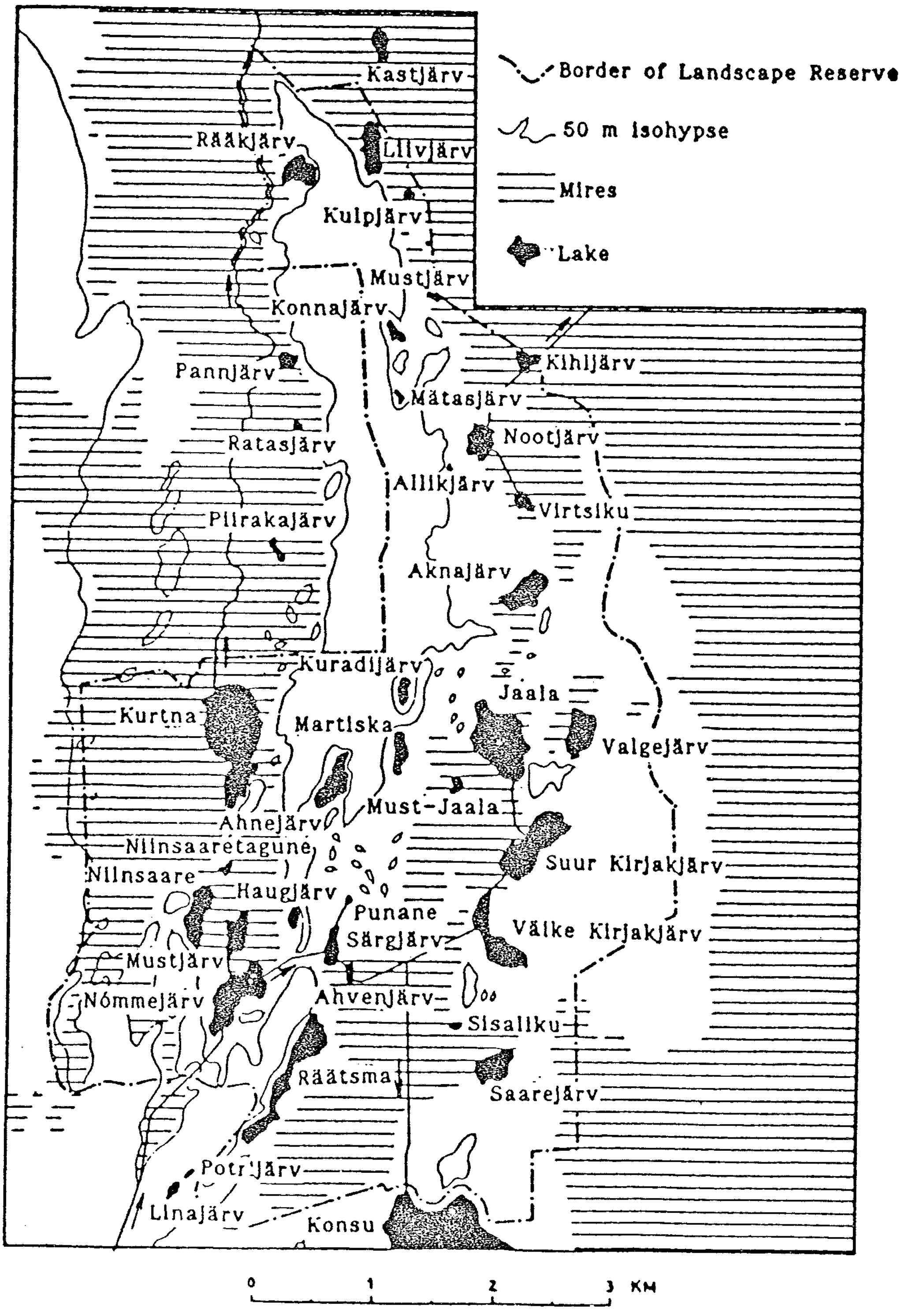


Fig. 9.8. The temporal dynamics of *Pinus sylvestris* tree ring width (mm, mean for five years for five sample trees) in the Liivjärve (A) and Niinsaare bogs (B).

KURTNA LAKES

Kurtna lakes include 40 lakes of different sizes and depths, and with different hydrobiological characteristics. Some of the lakes are linked by canals, ditches, or streams. The largest of them are Konsu, Kurtna Suurjärv, Jaala, Räätsmäe (the only iron-rich lake in Estonia), Suur Kirjakjärv, Väike Kirjakjärv, and Valgejärv (where the plant rarity — water lobely — *Lobelia dortmanniana* — grows).



ÖKOLOOGIA INSTITUUT, EESTI TEADUSTE AKADEEMIA

INSTITUTE OF ECOLOGY, ESTONIAN ACADEMY OF SCIENCES

Jaan-Mati Punning (editor)

THE INFLUENCE OF NATURAL AND ANTHROPOGENIC FACTORS ON THE DEVELOPMENT OF LANDSCAPES

The Results of a Comprehensive Study in NE Estonia

Publication 2/1994

Human Impact on the Development of the Vegetation of the Kurtna Kame Field in Northeastern Estonia

Abstract

The Kurtna Kame Field area, which is situated between the coastal area with its early agriculture and the inland forested area was selected for detailed studies. Pollen data from three lakes and two bogs of different size and developmental history demonstrate that several factors both natural and human induced influence the formation of pollen spectra. Because of the variety of landscape and soil types the biological diversity is high here and many taxa used in Central Europe as indicators of human impact exist in natural habitats in Estonia. Therefore, an exact reconstruction of human impact is difficult and only the appearance of pollen directly indicating agricultural activity can be used for that purposes. The distribution of the *Cerealia* pollen gives evidence that agriculture was developed in the vicinity of the Kurtna Kame Field at least since 1500 BP.

INTRODUCTION

Past landscapes cannot be observed or described directly. Their composition, structure and development must be reconstructed from the available palaeoecological and archaeological evidence. For that purpose pollen analysis is widely used. In interpreting the results of pollen analysis various possibilities exist for reconstructing the development of the environment through the general trends in development of the flora, both those resulting from changes in the physical environment and those caused by human impact.

In the more densely populated areas of Western and Central Europe, the variations in pollen content preserved in sediments covering the last 5000 years (Behre, 1986 ; Berglund, 1986 ; Berglund *et al.*, 1991 etc.) are mainly associated with human influence. In peripheral areas, such as Estonia, both natural and anthropogenically influenced processes are observable. To distin-

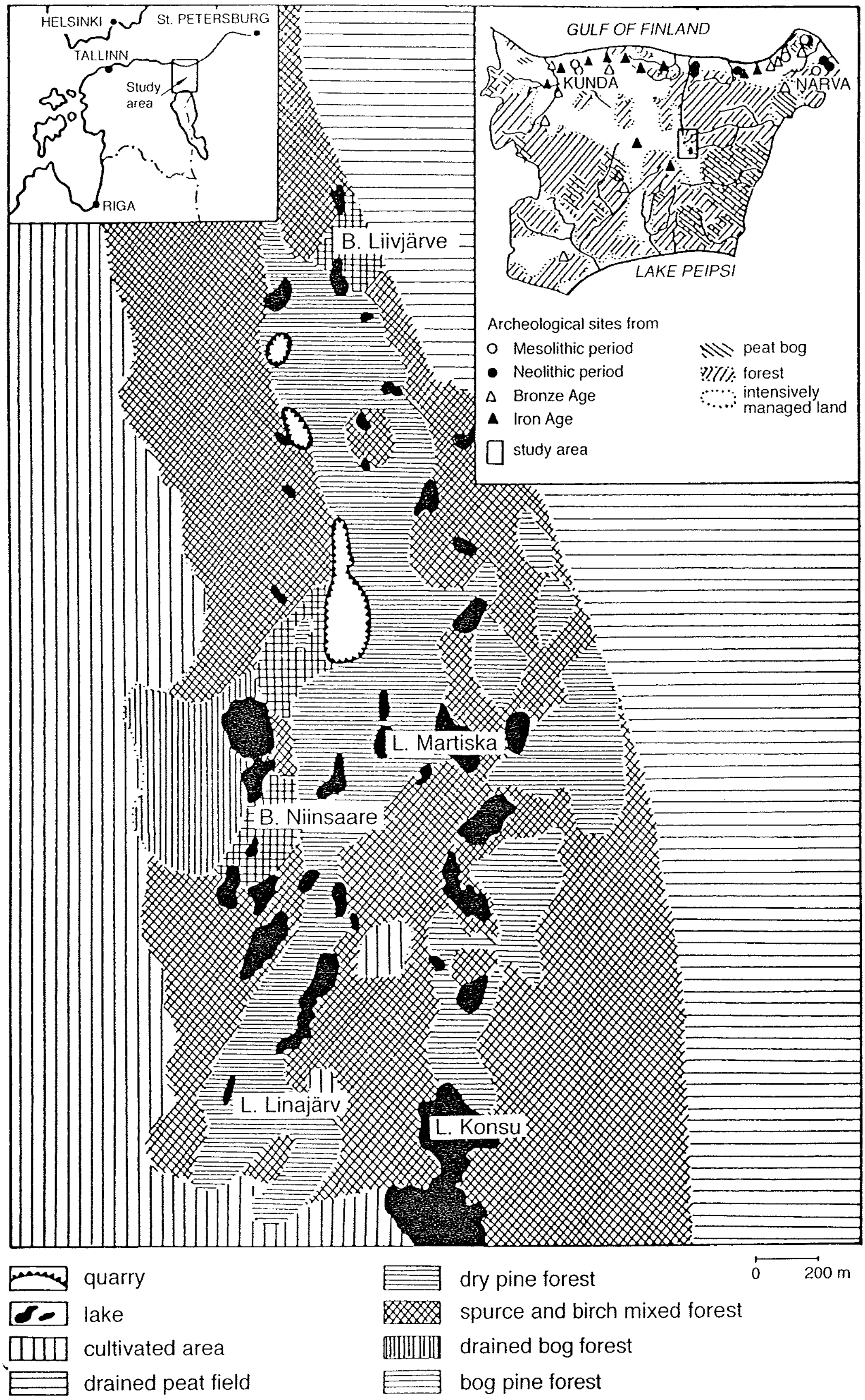


Fig. 1. Location of the study area and the sites investigated.

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The Results of a Comprehensive Study in NE Estonia

Publication 2/1994

9. HUMAN IMPACT ON BOGS

Edgar Karofeld

9.1. Introduction

Direct human impact on mires by drainage and peat cutting started in Estonia at least at the end o the 19th century and was most intensive in the 1950s - 1960s. Nowadays some 70% of the Estonia mires are drained or influenced by drainage (Пomets, 1993).

During the last 20 - 30 years the mires in north-eastern Estonia are greatly influenced also by indi rect human impact such as air pollution. The bogs are especially sensitive to air pollution becaus they receive all the nutrients through atmospherical inputs only. The industry in north-eastern Esto nia emits to the atmosphere about 400 thousand tons of pollutants, mainly calcium rich alkalin (pH 12) oil shale fly ash and ca 150 thousand tons of SO_2 annually (Chapter 6). The increased at mospheric input and alkaline precipitations (pH up to 8; Tôugu, 1987) have caused importan changes in environmental conditions, plant cover etc. in bogs of north-eastern Estonia. In fens th changes caused by increased atmospheric influx are less essential.

The influence of air pollution on bogs is well-known in industrial Western Europe, where remark able changes in the plant cover were observed ca 150 years ago (Tallis, 1964; Adams & Preston 1992). The changes in the chemical composition of peat and bog water as well as in the plant cove of bogs close to air pollution sources in North America have been also described (Gignac & Beck ett, 1986; Glooschenko, 1989).

As the consequences of the direct human impact on mires (burning, drainage, peat cutting etc.) ar comparatively well studied, this paper will mainly concentrate on those changes which can occu on bogs under indirect human impact. In order to study the changes nine bogs with a thickness o peat layer over 5 m at a distance of 2 - 25 km from the main air pollution sources (Fig. 6.1.) wer selected (Fig.9.1). Also some reference bogs in Central and SW Estonia with no essential huma impact were studied. The plant cover of the still virgin bogs in north-eastern Estonia is dominate by *Sphagnum fuscum*, *S. magellanicum*, *S. cuspidatum*, *Calluna vulgaris*, *Empetrum nigrum* *Ledum palustre*, *Andromeda polifolia*, *Oxycoccus palustris* (Kask, 1982; Masing, 1982). *Pinu sylvestris*, 3 - 4 m high with different growth forms, is the most common tree species (Roosaluste 1982). In virgin bogs the pH value of bog water is usually 3-4 and the content of minerals mainl less than 2 mg l^{-1} (Valk, 1988).

IMPACT OF NATURAL AND MAN-MADE PROCESSES ON THE DEVELOPMENT OF LAKE LINAJÄRV, NE ESTONIA

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Abstract. To obtain objective information about human impact on Lake Linajärv a comprehensive study of a sediment core was performed using geochemical (heavy metals, stabile isotopes of carbon and oxygen) and biological (pollen, diatoms, cladocerans) methods. For dating the ^{14}C and ^{210}Pb methods and soot-ball distribution were used. The obtained data enabled us to reconstruct the development of the lake during the Holocene and establish the relationships between the influencing external forces and the changes in the biogeochemical matter cycle as well as in the biotic communities in the ecosystem. These baseline data allow of the separation of human impact from natural factors.

Key words: paleoecology, historical monitoring, human impact, biogeochemistry, biostratigraphy.

INTRODUCTION

Objective information about the human impact on the biogeochemical matter cycle and the development of ecosystems can be obtained only on the basis of comprehensive investigations of the natural processes in the study area. Variable natural conditions and corresponding reactions in the development of landscapes lead to essential changes in the geochemical matter cycle. The formation or disappearance of geochemical barriers may cause total reorganization of the state and structure of ecosystems. The changes in energy flows lead to the reforming of biotic communities in ecosystems. As a result of these processes the ecosystem will reach a new state, which will determine its further development.

An understanding of these processes is of principal importance for reconstructing the dynamics of ecosystems in the past, the estimation of human impacts on the environment, and for compiling scenarios for the main trends of ecosystems under different land-use regimes. Therefore, the paleoecolocical approach, which is based on the study of bog and lake sediments, is widely used in the landscape study (Berglund, 1991; Mannion, 1989; etc).

In this research the paleoecological—geochemical approach was used to study the lacustrine sediments in Lake Linajärv in NE Estonia.

STUDY AREA

Lake Linajärv, a small closed lake, is situated in northeastern Estonia (59° 14′ N, 27° 32.5′ E, 48 m above sea level). The dominating relief form in this area is the Kurtna (Illuka) Kame Field, formed on the marginal formation of the last continental glaciation period, during the Pandivere stage about 12 200—12 300 years ago. The relief is rich in glaciokarstic hollows, where most of the lakes were formed during the Preboreal climatic period. The main natural factors influencing the dynamics of the environment in this area were changes in different hierarchic climatic conditions (besides global ones, regional changes related to the dynamics of the Baltic Sea) and the tectonic uplift (especially its glacioisostatic compound). The latter had an important influence on the hydrological regime, and therefore also on the paludification and water-level changes in the lakes.

Before World War II the human impact in the region was rather modest and consisted mainly in surface water regulation to drain the surrounding bogs and pastures. A sharp increase in human activities occurred in the early 1950s. Of major importance was the use of some waterbodies as reservoirs for industrial water supply. The use of groundwater, which started in the 1970s, resulted in a considerable drop of the water level in several lakes and a consequent shore and slope erosion. In 1951 the oil-shale-fired Ahtme Power Plant was built only a few kilometres from Lake Linajärv. During the 1960s and 1970s several larger powerf plants, emitting a huge amount of fly ash, were built in northeastern Estonia. Fly ash deposition caused an increase in the accumulation rates of several chemical elements in the sediments (Varvas & Punning, 1993).

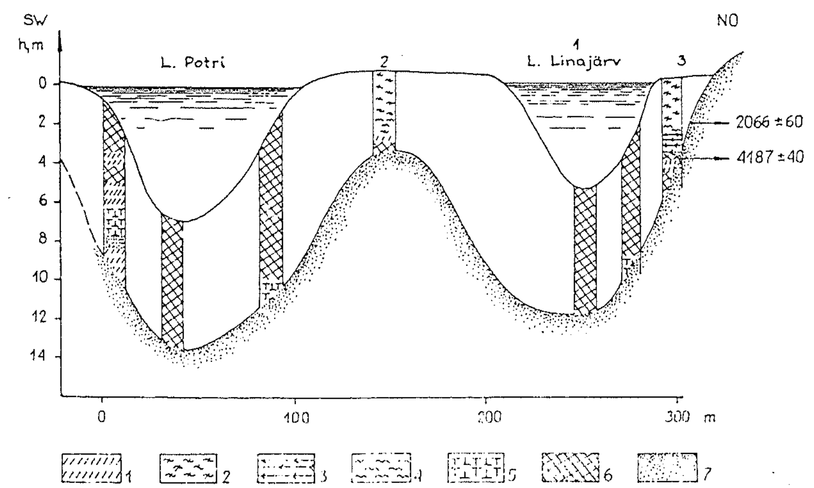

Fig. 1. The profile of the sites studied.
1, Bryales peat; *2, Sphagnum* peat; *3, Carex* peat; *4, Scheuchzeria* peat; *5*, lime; *6*, gyttja; *7*, sand and gravel.

Article

Jaan-Mati Punning, Mati Ilomets, Agu Karindi, Ants Martins and Hugo Roostalu

Greenhouse Gas Emissions: Recent Trends in Estonia

...s widely accepted that the increase in greenhouse gas (...HG) concentrations in the atmosphere, due to human ...vities, will result in warming of the Earth's surface. The ...ldwide project within the *Framework Convention on ...nate Change* was generated by the initiative of United ...ions, to examine this effect and better understand how ...e GHG increase in the atmosphere might change the ...nate in the future, how ecosystems and societies in ...erent regions of the world should adapt to these ...anges and what must policymakers do for the mitigation ...that effect. Estonia is one of more than 150 countries ...ich signed the *Framework Convention on Climate ...ange* at the *United Nations Conference on Environment ...d Development* held in Rio de Janeiro in June 1992. In ...94, a new project, Estonian Country Study, was initiated ...thin the U.S. Country Studies Program. The project will ...p to compile the GHG inventory for Estonia, investigate ...e impact of climate change on Estonian ecosystems, and ...e economy, as well as to formulate national strategies ...r Estonia to address global climate change.

INTRODUCTION

...fore the reinstatement of independence, in 1991, the economy ...d land-use planning in Estonia were not based on local inter-...but in most cases carried out in accordance with the politi-... military, and economic interests of the former Soviet Un-... Due to the considerable expansion of industry, often ...ipped with obsolete technology, extensive concentrations of ...iculture and use of natural resources, low levels of under-...nding of environmental sensitivity by immigrants, and often ...rly educated workers engaged in industry, the state of the en-...nment became rather critical at the local level.

Since 1991, Estonia has experienced a complicated political ...economic adjustment period, resulting in a substantial drop ...domestic agricultural and industrial trade relations, which ...ked severe deterioration of the national economy. However, ...eral political, institutional, legal and economic changes have ...ently been successfully implemented, thus improving the con-...ons for future development. Further structural reforms and ...or investments will be required to ensure environmentally-...nd economic development. To determine the measures for ...ustrial development in accordance with environmental limi-...ns, objective information about pollution activities is of the ...ost importance.

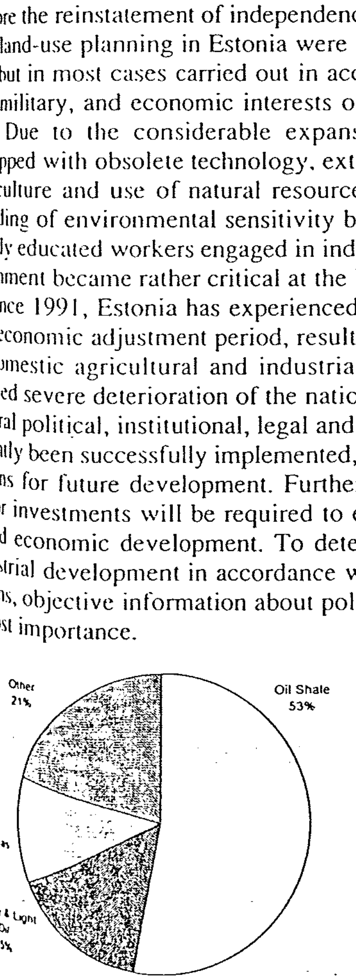

Figure 1. Fossil fuels for energy production.

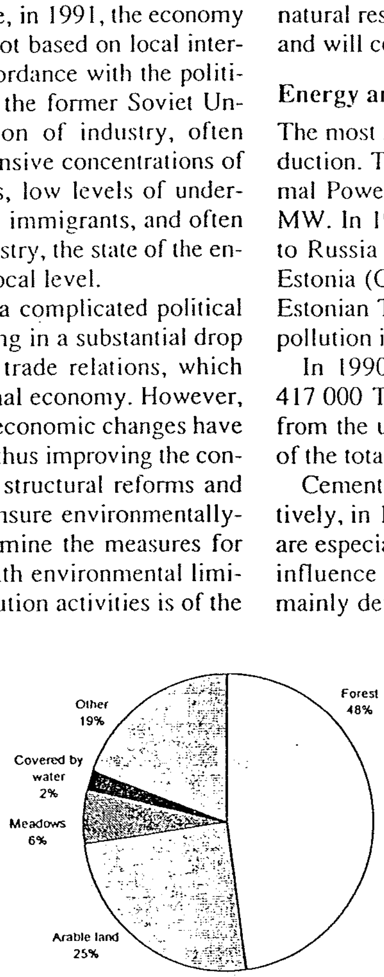

Figure 2. The structure of land-use on 1 Jan. 1993 (7).

This paper deals with the first results of greenhouse gas (GHG) emissions inventories in Estonia. The data have been compiled for the baseline year 1990, according to the methodology of the Intergovernmental Panel on Climate Change (IPCC). As radical changes have taken place in the Estonian economy, there has been a trend of rapidly decreasing GHG emissions; ca. 40% within the last 3–4 years. The present study is the first attempt to provide a GHG inventory for Estonia, to document changes and to estimate the efficiency of measures elaborated for the decrease of emissions in Estonia.

BASIC INFORMATION

Nature

Estonia is situated in the northwestern part of the flat Eastern European plain, and is within the Baltic Sea drainage basin. The total area of Estonia is 45 216 km^2, including 4132 km^2 (9.2%) made up of more than 1500 islands. Out of a total population of 1 575 000 (1990 census), 71.4% live in urban areas. Estonia is characterized by a flat topography with an average elevation of about 50 m, the highest point being 318 m a. s. l.

Although not very large in area, Estonia is relatively rich in natural resources, both mineral and biological, which have been and will continue to be the basis of the Estonian economy.

Energy and Industry

The most important branch of industry in Estonia is energy production. The total power yield of the Estonian and Baltic Thermal Power Plants (TPP) in northeastern Estonia is about 3000 MW. In 1990, about half of the energy produced was exported to Russia and Latvia. About 75% of the pollutants emitted in Estonia (CO_2, SO_2, NO_x, fly-ash) originate from the Baltic and Estonian TPP, which rank among the 10 biggest sources of air pollution in Europe.

In 1990, the Estonian energy system consumed a total of 417 000 TJ of fuel. Estonia meets most of its energy demand from the use of fossil fuels. In 1990, oil shale constituted 53% of the total energy production (Fig. 1) (1).

Cement and lime production (938 and 185 000 tons, respectively, in 1990), food production, and some chemical industries are especially important among industrial activities and directly influence the GHG budget. The chemical industry has been mainly developed based on oil shale and imported raw materials (natural gas, apatite), for the production of fuel oil, aromatic hydrocarbon, phenols, solvents, cosmetics, and pesticides (1).

Land Use

Estonia is rich in renewable natural resources (Fig. 2). During the last half-century the area of forest has more than doubled, making up ca. 19 200 km^2 (47.7 % of the total land area) of the Estonian territory in 1990 (2). This includes closed forests, in addition to young forest plantations, open woodlands and forested peatlands. The total standing volume of forests is 264 million solid m^3, the average standing volume being 144 solid m^3 ha^{-1} (3). The Estonian forests belong to the zone of mixed

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and coniferous forests with relatively favorable growth conditions.

Despite the small area of forestland, the Estonian forests are rather diverse. The great variability due to the natural conditions (soil quality, relief, climatic differences) is also influenced by human activities, e.g. cutting, drainage, fires, etc. in the majority of the forests.

Estonian agriculture is specialized in livestock breeding, with cattle-breeding being the most important. Of the total arable land 55% is covered by grasslands and 38% by grain fields. The main cereal (barley) accounts for more than 60% of the total sown area of grain crops. Meadows and natural or seminatural pastures are also common (4).

The area of peatlands is approximately 10 000 km^2, corresponding to 22% of the territory (partly coinciding with forest area), and their contribution to the GHG balance is significant, as the changes in the hydrological regime are reflected in changes in emissions of CO_2 and CH_4. During the last few decades, Estonian peatlands have been heavily influenced by the amelioration activities for agriculture, forestry and peat production. According to the published data (5), about 30% of Estonian peatlands are affected by drainage activities, but the real value might be twice this figure due to the lack of insufficient statistical data as well as to the influence of drainage activities in the surrounding areas. Most drastically affected are fens, swamps and floodplains. Only about 30–40% of the peatland area has not been subjected to human impact (6).

A remarkable variety of landscapes, climate conditions, types of bedrock and soil, lead to high biological diversity. As many as 8814 flora species and 12 070 fauna species are known. However, it has been suggested that the probable number of animals in the fauna of Estonia is about 35 000 (7). Some ecosystems are unique to Estonia, hence it is nessessary to pay special attention to the vulnerability of the ecosystems and landscapes, in the event of global climate change.

Economy

The Estonian economy is in a transition period, from centralized planning to a market economy, and this has brought about rapid changes in all sectors of state activities, particularly in the energy and industry sectors, thus complicating the analysis and modelling of emission projections. Therefore, it is a matter of urgency to compare emission data with a baseline year, and to follow the trends in the course of economic stabilization.

Before World War II, mainly agriculture, light industry and food industry were developed in Estonia. At the beginning of the 1950s, special attention was given to the development of heavy industry based on imported raw materials and migrant labor. Priority was given to the development of an energy industry based on local oil shale. Electricity generation is concentrated in two oil-shale-fired power plants in northeastern Estonia. These plants were designed to supply the northwestern region of the former USSR, and approximately 50% of the electricity was exported. In the years 1990–1994, power production was reduced due to the decrease in export and to the restructuring of Estonian industry. This resulted in the decrease of oil-shale consumption for power generation from 22.4 million tons in 1990 to 15 million tons in 1993 (1, 8).

According to preliminary calculations (8), the Gross Domestic Production (GDP) in 1993 was 22.8 billion Estonian kroons (1 DM is 8 EEK). From 1990 to 1993, the GDP decreased. Some growth in GDP occurred in 1994 (Table 1), and further improvement is expected (9).

GREENHOUSE GAS INVENTORY: 1990

Methods and Data Sources

The GHG Inventory for Estonia was compiled for energy, industry, transport, agriculture, forestry and land-use sectors, and wetlands. For estimating the emissions of GHG, IPCC methodologies were used (10).

The main sources of data are Statistical Yearbooks and other publications issued by the Estonian Statistical Office (1, 8, 11–14). Unfortunately, the availability and reliability of data from different sectors differ considerably. Data on GHG emissions for wetlands are preliminary, and there is presently no basis from which to deduce natural and anthropogenic components of the GHG budget for wetlands.

Energy

Energy-related activities are the most significant contributor to Estonian greenhouse gas emissions. The production, transmission, storage and distribution of fossil fuels also serve as sources for greenhouse gases, as do primary fugitive emissions from natural-gas systems, oil-shale mining and shale-oil production.

Table 2 shows CO_2 and non-CO_2 emissions from energy use and transport in Estonia for 1990.

Estonia satisfies most of its energy demand from fossil fuels, and approximately 68% of the CO_2 emissions in Estonia are released by the combustion of oil shale. The remaining 32% comes from heavy fuel oil, natural gas, coal, light fuel oil, and other fuels. From the point of view of greenhouse gas emissions it is important that during combustion of oil shale, CO_2 is formed not

Table 1. The dynamics of GDP.

Year	1990	1991	1992	1993	1994
GDP against previous year, %	–8.0	–14.0	–14.2	–6.7	+3.5
GDP against 1989, %	92	79	68	63	65

Table 2. Annual CO_2 and non-CO_2 emissions from energy use and transport, Gg. (Annual levels 1990).

Sector	CO_2	CH_4	N_2O	NO_x	CO	NMVOC
Energy conversion	28 461	0.05	0.002	35.78	7.33	NA
Residential	1 588	0.46	0.425	3.04	0.97	NA
Commercial	1 581	0.12	0.954	3.13	1.62	NA
Industrial	2 897	0.05	NA	4.81	1.67	NA
Transport	2 655	1.93	0.036	32.64	171.95	22.92
Total	37 183	2.61	1.417	79.41	183.54	22.92

Note: The totals provided here do not reflect emissions from bunker fuels used in international transport activities.
NA - not available, NMVOC - nonmethane volatile organic compounds

Table 3. Annual CO_2 emissions from industry. (Annual levels 1990).

Source	CO_2, Gg
Cement production	467.6
Lime production	145.3
Total	612.9

Table 4. Annual methane emissions from waste. (Annual levels 1990).

Source	CH_4, Gg
Municipal landfills	26.3
Municipal wastewater	0.9
Industrial wastewater	15.2
Total	42.4

ly as a burning product of organic carbon, but also as a decomposition product of mineral carbon (15). Therefore, the total quantity of CO_2 increases up to 25% in flue gases from oil-shale burning.

A formula compiled by Martins (15) for the calculation of Estonian oil-shale carbon emission factor, taking into consideration the decomposition of its carbonate part is:

$$CEF_{oil\ shale} = 10\ \frac{C_t^r + k(CO_2)_M^r\ 12/44}{Q_i^r}\ (tC/TJ) \qquad \text{Eq. 1.}$$

here: Q_i^r is net caloric value oil shale as it burned, MJ kg^{-1};
C_t^r is carbon content of oil shale as it burned, %;
$(CO_2)_M^r$ is mineral carbon dioxide content of oil shale as it burned, %;
k is decomposition rate of the ash carbon part (k = 0.95–1.0 for pulverized combustion of oil shale) (15).

Net calorific value of oil shale is changeable, with a tendency to decrease, because the oil shale layers with best quality are already exhausted. In 1990, medium net caloric value of oil shale burned in power plants, was 8.6 MJ kg^{-1}.

Calculation of oil shale carbon emission factor gives:

$$CEF_{oil\ shale} = 10\ (20.6 + 0.95 \times 17.0 \times 12/44)\ 8.6 = 29.1,\ (tC/TJ) \qquad \text{Eq. 2.}$$

Industrial Processes and Wastes

During cement and lime production thermal processing of calcium carbonate ($CaCO_3$) from limestone, chalk or other calcium-rich materials gives calcium oxide (CaO) and carbon dioxide (CO_2). Total CO_2 emissions from Estonian cement and lime production are given in Table 3.

In Estonia, methane emissions from waste come mainly from landfills, domestic and commercial wastewater treatment, and industrial wastewater (Table 4). Organic landfill materials such as municipal waste, including waste food and waste paper, can decompose and produce methane by anaerobic decomposition. Methane production usually begins 1–2 years after the waste delivery to the landfill and continues for a long time (> 50 years).

Agriculture

The main GHG sources in the Estonian agriculture are animal husbandry and fertilizer use. Estonian agriculture is specialized in animal husbandry, which is responsible for 65–70% of the total CH_4 emissions from agriculture.

In 1990, the total sown area was 1 100 000 ha whereas the forage crops covered 665 400 ha, cereals and legumes 397 100 ha; potatoes, vegetables and industrial crops were 4.1, 0.5 and 0.3% of the total sown area, respectively (16).

Restructuring of agricultural production, development of the private sector, partial loss of the traditional eastern market and the search for new ones, as well as the increases in prices for fuel and fertilizers have greatly influenced the whole agricultural sector. In 1995, the total sown area had decreased to 925 400 th ha, the sown area of cereals and legumes was 302 000 ha, and potatoes were cultivated on 37 600 ha (17).

The use of fertilizers and pesticides has also decreased. In the 1980s, 100–120 kg of the nitrogen from mineral fertilizers, and 60 kg from organic fertilizers were used per ha of arable land. Compared to 1985, the use of mineral fertilizers and manure in agriculture has decreased 5-fold and 2-fold, respectively (17).

In 1983, when animal husbandry was at its highest,methane emission from enteric fermentation and livestock manure management was 68.2 Gg (Fig. 3). By 1990, it had decreased to 64.1 Gg, and in 1995 it was only 35.5 Gg. Ruminants, including cattle, sheep and goats, are the largest producers of CH_4 (88% of CH_4 emissions were from cattle raising, and 8.7% from pig husbandry). Methane emission from enteric fermentation accounted for 87% of the total CH_4 emissions in agriculture.

The amount of methane produced during the decomposition of manure depends on type and population size of animals, and manure-management methods. Swine manure is the greatest emission source, making up about 48% of the total methane emissions from livestock manure.

Nitrous oxide production and emissions from soils are influenced by soil properties, crop type, management regimes, amount of nitrogen fertilizers and organic manure used, biological fixation of nitrogen, etc. Nitrous oxide emissions from commercial and organic fertilizers were estimated using the methods suggested in the IPCC Guidelines (10). At present, nitrous oxide emissions are 2–3 times lower than in the 1980s, when relatively large amounts of fertilizers were used (Fig. 4).

Wetlands

The total area of wetlands is ca 1 231 700 ha, of which lakes cover about 207 000 ha, marshes some 5000 ha, and the rest (ca. 83%) is in peatlands. During the last decades Estonian peatlands have been significantly influenced by amelioration activities, mostly for agricultural and forestry purposes. The role of the peat industry is considered to be somewhat less important.

An up-to-date assessment of the ecological state of peatlands in Estonia has not been made. According to official data, about 120 000 ha of peatlands have been drained for agricultural pur-

Figure 3. Methane emissions from enteric fermentation and livestock manure management.

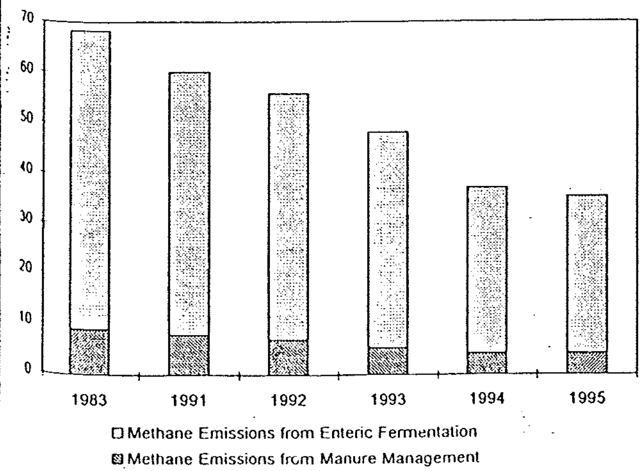
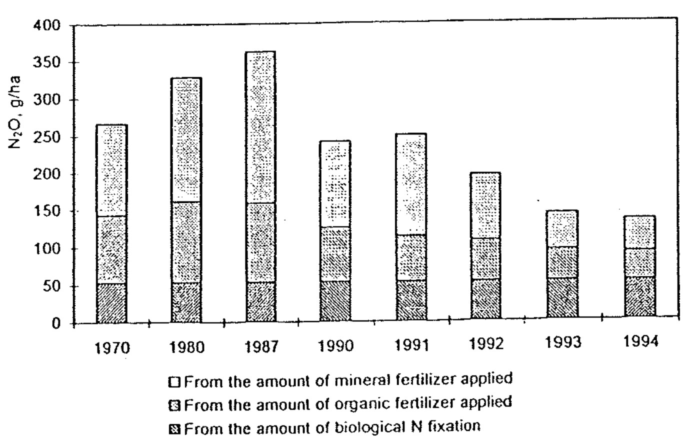


Figure 4. Nitrous oxide emissions from fertilizers used in agricultural enterprises and private farms (emission coefficient C = 0.0036 N emitted as N_2O/N applied).



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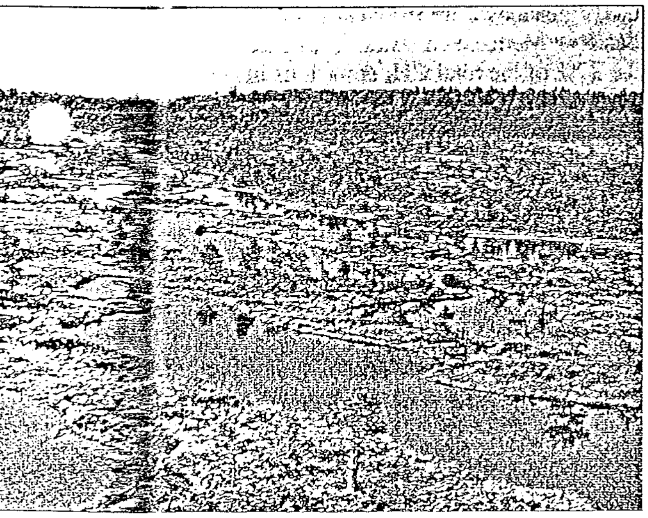
poses, some ... ha for the needs of forestry, and ca. 38 000 ha to satisfy ... ands of industry (5). The total value of about 340 000 ha ... ed peatlands does not correspond to the actual area affected by drainage peatlands, since the data show only the area of ... ate amelioration systems. Also, the outflow ditches and facilities outside the systems greatly expand the affected ... d have not been taken into account.

As Nyst...) estimated, for drainage by peat harvesting, the drainage ... ct on the area outside the edge ditches may range from ... 30%, while the average value of the drainage impact on ... vested area of the same size is 90%. Consequently, by ... lying the official drainage value by a factor of 2, we ... each a more realistic estimate of the area of peatlands ... by drainage. Most drastic has been the impact on fens, ... nps and floodplains, since only about 10% of them are ... virgin state. Less important is the influence of drainage ... *Sphagnum* dominated bogs. The anthropogenic impact ... e state of lakes and marshes has resulted in a drop in the ... level in very exceptional cases only.



Pool-ridge complex, Männikjärve bog, Endla Mire System, Central Estonia. Photo: M. Ilomets.

Our data ... ate that peat accumulation in different types of peatland vary ... ly slightly; ranging between 1.5 and 1.9 t ha^{-1} yr^{-1} (6). We base our calculations on a mean value of 1.7 t ha^{-1} yr^{-1}. In lakes, the accumulation of organic sediments (mud) is highly variable from 1 to 100 mg cm^{-2} yr^{-1}, and we take a representative value of 10 mg cm^{-2} yr^{-1} or 1 t ha^{-1} yr^{-1}. Considering the carbon content of 54% in the dry matter, both in peat and lake sediments, the mean accumulation of CO_2 in the virgin peatlands is about 3.37 t ha^{-1} yr^{-1}. The corresponding value in lakes is ca 1.... t ha^{-1} yr^{-1} as the ash content in Estonian lake muds is about ...% (19).

As a result of the drainage of virgin peatlands, the accumulation of organic matter has ceased, and due to intensive decay processes the mineralization of organic matter has increased. For several decades the breakdown of peat resources and peat losses in the minerotrophic fens that have been ameliorated for agricultural purposes have been monitored. It has been shown that the mineralization of organic matter is about 15 to 20 t ha^{-1} yr^{-1} during the first decade after the establishment of an amelioration system (20). Later, the process stabilizes and, depending on the character of exploitation (crop field, grassland, pasture), may remain between 5 and 15 t ha^{-1} yr^{-1}, depending somewhat on management method. The possible average level may be about ... ha^{-1} yr^{-1}, or 15.8 t of CO_2. Franzén (21) concluded that after drainage the annual amount of peat decomposition remained within the range of 15 to 124 times the mean annual peat accumulation. It has also been shown that the rate of peat mineralization in bogs and swamps is quite probably about the same level as that in fenlands.

The calculations indicate that human activities have most drastically affected the carbon budget in fens, swamps and floodplains where the CO_2 accumulation has decreased from 638 to 169, from 378 to 37 and from 117 to 22 Gg yr^{-1}, respectively. Correspondingly, the CO_2 emission has increased per year from 3153 to 5350 Gg in fens, from 920 to 2391 Gg in swamps, and from 836 to 1294 Gg in floodplains. The values for raised bogs, lakes and marshes have not changed significantly. In total, CO_2 emissions have increased about 1.8 times during the period of 20 years (from 1970 to 1990). The values for methane emissions are one magnitude lower and their changes are not so substantial. Methane emissions from peatlands have decreased about 2.2 times (from 18 to 8.1 Gg yr^{-1}. The trends of carbon fluxes from wetlands since 1950 are given in Figure 5.

RESULTS

The results of the GHG inventory in Estonia in 1990 are given in Table 5 (12). Fossil fuel combustion is the main source of CO_2, comprising some 94% of the total. The accumulation of carbon by forests (7950 Gg CO_2 in 1990) was more than offset by the loss of CO_2 from wetlands. The emission of CH_4 and N_2O was also mostly connected with the energy sector.

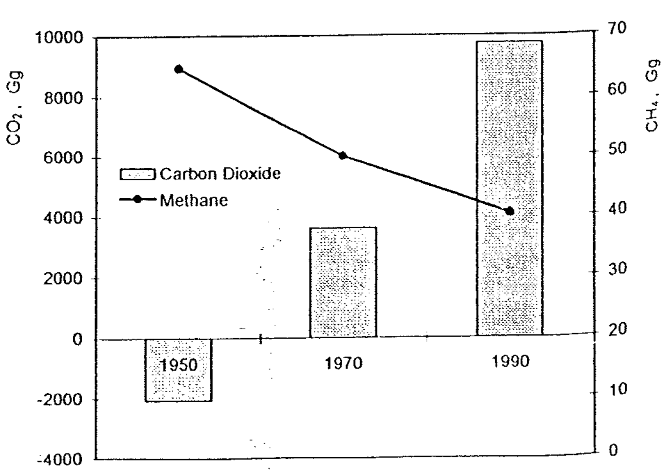
The GHG emission data (Table 5) show, that in the Baltic Sea region Estonia had the highest per capita emission of GHG in 1990 (Table 6).

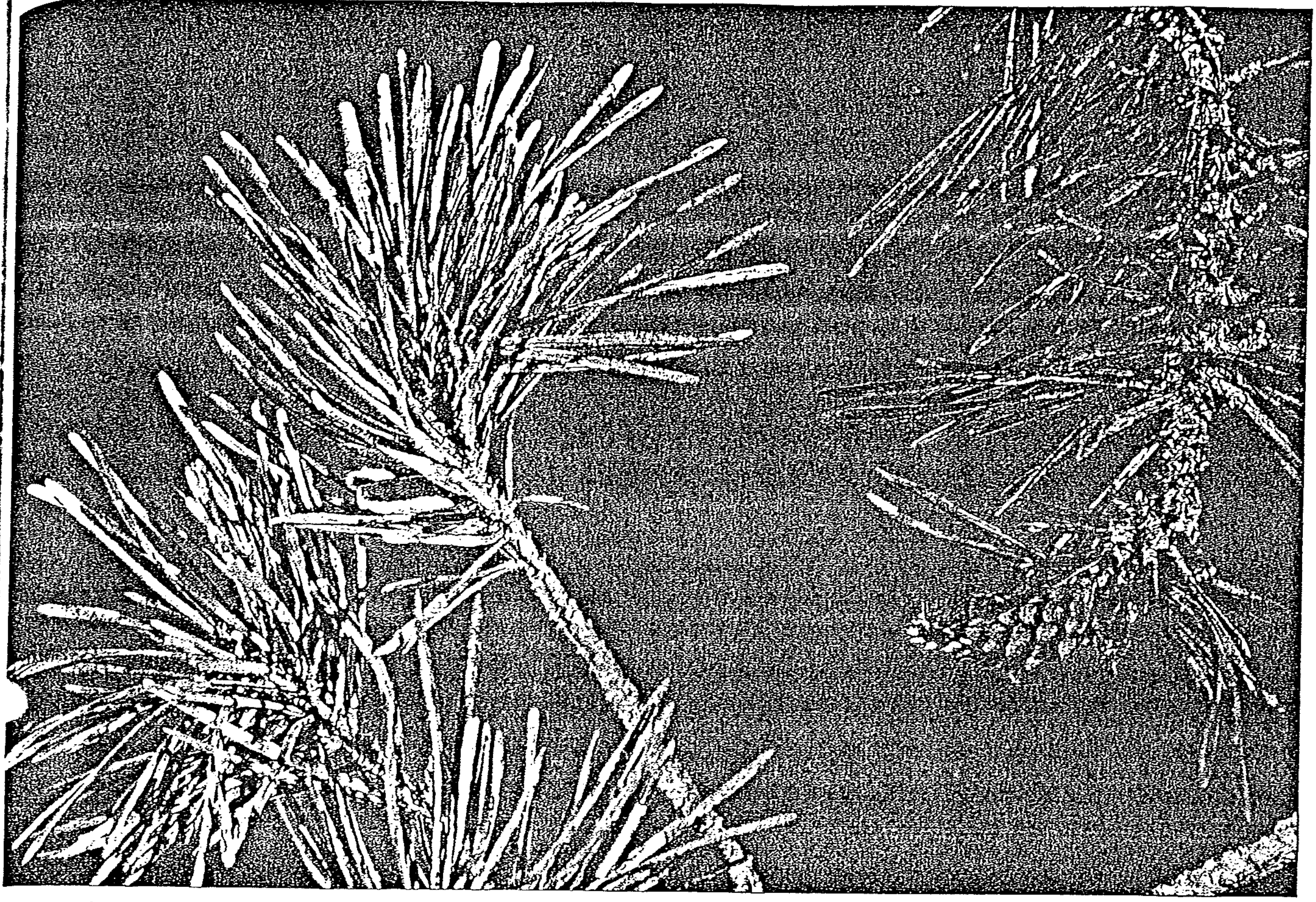
RECENT TRENDS IN GHG EMISSIONS: 1991–1993

Since 1990, major changes have occurred in the Estonian economy, especially in the energy sector. In only a short time span the power-intensive and material-consuming industries that were subsidized by abnormally low fuel prices, totally collapsed economically. The import of fossil fuels decreased substantially as prices of imported fuels increased rapidly to world market levels. Figure 7 shows the price increase for different fuels in the period of 1991–1993. As the price increases for different types of fuel varied, changes in the structure of fuel consumption were significant.

The export of electric energy decreased sharply: from 8477 GWh in 1990 to 1596 GWh in 1993 (8). As a result, during 1990–1993 the total use of fossil fuels decreased by 43.8%, that of natural gas by 70.8%, coal by 68.3%, liquid fuels by 52.8%, and oil shale by 35.6% (30). During these years the total emission of CO_2 from energy production and use decreased by 41.5%. While in 1990, Estonia was in fifth place in the world in emis-

Figure 5. Carbon fluxes (Gg yr^{-1}) from wetlands in 1950, 1970 and 1990.





Calcareous dust emitted from building materials, industry, power engineering, oil-shale processing in northern Estonia, is one of the factors resulting in disturbances of CO_2 balance in forests. Photo: M. Madre.

Table 5. Trends in some GHG emissions, Gg.

Source and sink categories	CO_2 1990	CO_2 1993	CH_4 1990	CH_4 1993	N_2O 1990	N_2O 1993
Fuel combustion	37180	21750	3	2	1.4	0.9
Fugitive fuel emissions	NO	NO	217	105	NO	NO
Industrial processes	610	190	NA	NA	NA	NA
Agriculture	NO	NO	60	48	0.9	0.5
Land use change and forestry	−7950	−7660*	NE	NE	NO	NO
Wetlands	9750	9750	NE	NE	NO	NO
Wastes	NO	NO	42	28	NO	NO
Total	39590	24030	322	183	2.3	1.4

NA - not available NO - not occurring NE - not estimated
* data of M. Mandre

Figure 6. The increase of fuel prices (Estonian kroons t^{-1}) (1 DM = 8 EEK) 1990–1995.

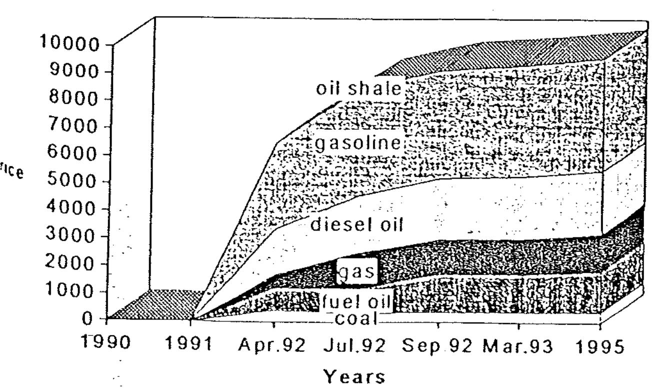


Table 6. GHG emission per capita in the Baltic Sea region countries in 1990, tonnes.

Country	CO_2	CH_4	Reference
Estonia	25.2	0.35	this work
Latvia *	8.6	0.6	22
Lithuania **	10.0	0.008	23
Poland	9.53	0.15	24
Finland	10.34	0.005	24
Sweden	7.04	0.004	25
Denmark	9.93	0.09	24
Norway	9.10	0.08	24
Global mean	4.22	NA	24

* without wetlands
** only combustion related emissions
NA not available

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The effects of alkaline fly ash precipitation on the *Sphagnum* mosses in Niinsaare bog, NE Estonia

Emäksisen tuhkalaskeuman vaikutus rahkasammaliin Niinsaarensuolla Koillis-Virossa

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In north-east Estonia, the precipitation of calcium-rich strongly alkaline fly ash from thermal power stations has caused significant changes in the local ombrotrophic mires. *Sphagnum* mosses disappeared from Niinsaare bog during the 1970s in the period of the highest air pollution. Their disappearance was probably caused mainly by the combination of high pH values and an increased concentration of calcium in the bog water. In Niinsaare bog, the present mean pH value of bog water is 5.3 ± 0.6 and the mean calcium concentration 11.6 ± 1.6 mg l^{-1}, compared with 3.7 ± 0.4 and 1.9 ± 0.2 mg l^{-1} in the uncontaminated Nigula bog respectively. During the last decade, following the reduction of fly ash emission, the *Sphagnum* mosses started to reappear in Niinsaare bog. Nine *Sphagnum* patches dominated mainly by *S. angustifolium, S. fallax and S. magellanicum* were studied from June 1991 to September 1995. During one year, the distance between the centre and edges of these patches increased on an average by 5.1 ± 2.7 cm and the area by 29 ± 21.5%. This indicates that the degeneration of *Sphagna* in NE Estonian bogs is not yet irreversible and, by reducing the air pollution in the long term, the restoration of *Sphagnum* carpet is possible.

Key words: atmospheric pollution, degeneration and recurrence of *Sphagna*, ombrotrophic mire

INTRODUCTION

The disappearance of *Sphagnum* mosses from bogs in industrial areas started ca. 150 years ago (Tallis 1964, Adams & Preston 1992) and still continues. There are several studies during the last decades from North America (Gorham et al. 1984, Gignac & Becket 1986, Austin & Wieder 1987) and West Europe (Tallis 1973, Smith 1978, Woodin et al. 1987, etc.) dealing with the effects of air pollution on bogs and *Sphagnum* mosses (Ferguson & Lee 1978–1980, Ferguson et al. 1978, Press et al. 1986, Bayley et al. 1987, Aerts et al. 1992). In these papers, the degradation of *Sphagnum* is explained mainly by the high SO_2 concentration in the air and high sulphur input. The ombrotrophic mires and *Sphagna* are especially sensitive to air pollution since they receive all their nutrients from the atmosphere.

Human impact on the history of Lake Nômmejärv, NE Estonia: a geochemical and palaeobotanical study

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A HOLOCENE RESEARCH PAPER

Abstract: A comprehensive geochemical and palaeobotanical study of the lacustrine sediments of Lake Nômmejärv from industrialized NE Estonia establishes the links between the nature and intensity of human activities and their impacts on the state and structure of the lake ecosystem. In cores of sediment formed during the last century, five zones can be distinguished, each reflecting a pattern of human activity and characterized by a particular diatom community and sediment composition. Using reliable geochronological data it is possible to compare these zones with the known industrial load on the lake and its catchment area. The information obtained is of practical value for planning the rehabilitation of this severely impacted lake.

Key words: Human impact, palaeoecology, lacustrine sediments, sediment chemistry, diatoms, ^{210}Pb, Estonia.

Introduction

Information on the past development of lake ecosystems can be obtained from the analysis of sediment cores: an approach used widely in landscape studies (Berglund, 1986; Mannion, 1991). In this paper the approach was used to study the lacustrine sediments of Lake Nômmejärv in NE Estonia. Three sediment cores were obtained from two different sites in the lake. The aims were to reconstruct the history of this aquatic ecosystem during the Holocene, and to identify the dominant factors affecting its trophic status, and the accumulation of heavy metals and other elements in the sediments. Special attention was paid to the uppermost 50 cm of the sediment sequence, formed under the rapidly increasing influence of the local oil-shale mining and processing industry, which started in AD 1916 and expanded in the 1950s and 1960s.

Study area

Lake Nômmejärv is situated in NE Estonia in the Kurtna Lake District, where 39 hydrologically diverse lakes have been exposed to increasing human impact over the last 50 years. The dominant relief form in this area is the Kurtna (Illuka) Kame Field, formed in the marginal area of the last continental glaciation about 12 200–12 300 years ago (Raukas *et al.*, 1971). The relief is especially varied due to numerous glaciokarstic hollows, in which most of the lakes were formed during the Preboreal climatic period. The main factors which influenced environmental development in this area were changing climatic conditions and tectonic, largely glacioisostatic, uplift. The latter strongly influenced the hydrological regime and therefore the paludification and water-level fluctuations in the lakes.

Before the second world war local human impact was restricted to lake water regulation associated with drainage of the surrounding bogs and pastures. The Raudi Creek, the natural inlet for Lake Kurtna, was redirected eastwards via lakes Nômmejärv, Särgjärv, Ahvenjärv, Väike- and Suur-Kirjakjärv (Figure 1), transforming the originally closed lakes by in- and outflows, and fundamentally effecting the lake water quality. Later, in the 1920s and 1930s, a military training area was constructed, with some buildings sited on the shoreline of Lake Nômmejärv.

Human impact increased sharply in the 1950s. Most importantly, Lake Konsu became a reservoir for industrial water supplies. To increase its catchment the inflow to Lake Nômmejärv was redirected into Lake Konsu. Simultaneously, another channel system was cut connecting lakes Kurtna, Niinsaare, Mustjärv and Nômmejärv. In the late 1960s the Raudi Creek was turned into an artificial channel and since 1970 has been used to discharge mine waters through lakes Nômmejärv and on ultimately to Lake Konsu (Vesiloo, 1987).

The first oil-shale power plant in NE Estonia was erected in 1937. Following this the Kohtla-Järve and Ahtme power plants were built in 1949 and 1951 respectively; the latter situated only

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CHARACTERISTIC FLY-ASH PARTICLES FROM OIL-SHALE COMBUSTION FOUND IN LAKE SEDIMENTS

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Abstract. Fly-ash particles accumulate in sediments and can be used to assess spatial distribution and temporal trends of atmospheric deposition of pollutants derived from high temperature combustion of fossil fuels. Previous work has concerned fly-ash derived from oil and coal. Oil-shale is the main fossil fuel used in Estonia and a major source of atmospheric pollution in the Baltic states. To assess if oil-shale power plants produce specific fly-ash particles, we used scanning electron microscopy (SEM) and energy dispersive X-ray analysis (EDX) to compare fly-ash particles from oil-shale combustion with particles from oil and coal combustion. Two types were analysed, large black (10–30 μm) and small glassy (<5 μm) spheroidal particles. Although particle morphology to some extent is indicative of the fuel burnt, morphological characters are not sufficient to differentiate between particles of different origin. However, our results indicate that with EDX analysis the fly-ash from oil-shale can be distinguished from oil and coal derived particles in environmental samples. Concentrations of large black and small glassy spheroidal fly-ash particles in a sediment core from an Estonian lake showed similar trends to oil-shale combustion statistics from Estonian power plants.

Key words: atmospheric pollution, fossil-fuel emissions, fly-ash particles, oil-shale, coal, oil, sediments

1. Introduction

Fly-ash particles from fossil fuel combustion have received considerable attention in recent years in studies of environmental pollution and lake acidification history (see reviews by Wik *et al.*, 1986; Wik and Renberg, 1996). Fly-ash particles accumulate in lake sediments and may be used for environmental analyses; surface sediments can be used for monitoring contemporary regional atmospheric deposition, while sediment cores can be used for analyses of historical trends. Most work has concerned spheroidal carbonaceous particles (Griffin and Goldberg, 1979; Wik and Renberg, 1996). However, inorganic aluminosilicate fly-ash spheres have also been analysed (Rose, 1990b, 1996). Fly-ash particle morphology and composition is to some extent indicative of the fuel burnt, and it has been suggested that scanning electron microscopy (SEM) (Griffin and Goldberg, 1981) and energy dispersive X-ray (EDX) analyses (Rose *et al.*, 1994) of individual fly-ash particles found in lake sediment records could be used to estimate the deposition of atmospheric pollution derived from different fuel types.

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Water, Air, and Soil Pollution **104**: 149–160, 1998.

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THE SENSITIVITY AND ADAPTATION OF ECOSYSTEMS TO THE DISTURBANCES: A CASE STUDY IN NORTHEASTERN ESTONIA

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Abstract. The study focused on the problem of the response and adaptation of an ecosystem to natural fire in case of greenhouse warming. The palaeoecological approach was used and reconstructions were made for time *ca* 6000 years ago, when the human impact in the studied area was absent or very weak and the summer temperatures were about 2.4 degrees higher than at the present time. The palaeoreconstructions were compiled using the charcoal, pollen and diatoms data from the sediments of a northeast Estonian lake. The results show that forest fires influenced the biota of the lake mainly through evapotranspiration and the accompanying erosional changes. The impacts of the fire directly to the lake ecosystem were short-term and the primary diatom association was restored after 10–15 years. The pollen influx was influenced by the fires mainly through the changes in the openness of the landscape and the composition of the pollen spectra was restored over a period of 50–60 years. The data demonstrate the high ability of the studied ecosystem to adapt to the impact of natural fires in the climatic environment comparable with that predicted for the future.

Key words: adaptation and self-regulation of ecosystems, charcoal, diatoms, Estonia, natural disturbances, palaeoecology, pollen analysis.

1. Introduction

The evolution and state of ecosystems are affected by different biotic and abiotic factors and processes of variable level and duration. Since the essense and intensity of these processes are very different, the intervals reflecting the results of the corresponding impact may last from seasons to hunderds of years. Therefore the study of the relations and mechanisms between the impact on ecosystems and its consequences is extremely complicated. Some advances may be offered by a palaeoecological approach. The information (biological, geochemical, lithological) stored in cumulative deposits (peat, lake deposits) allows us to follow the dynamics of natural processes over hundreds and thousands of years (Chambers, 1993; Carpentier *et al.*, 1995; Smol, 1995). If it is possible to correlate the palaeoecological information with certain events and impacts, the data obtained can be used for the reconstruction of cause-effect relationships and for modelling the dynamics of landscapes and ecosystems. In this way it is possible to characterize the adaptation of different ecosystems to the various impacts and compare the state of ecosystems in the past with those predicted for future climate change (Kont *et al.*, 1996).

Palaeogeographical and palaeoecological investigations have shown that concurrently with global and generally long-term processes, the evolution of ecosys-

Mitigation and Adaptation Strategies for Global Change 2: 1–17, 1997.

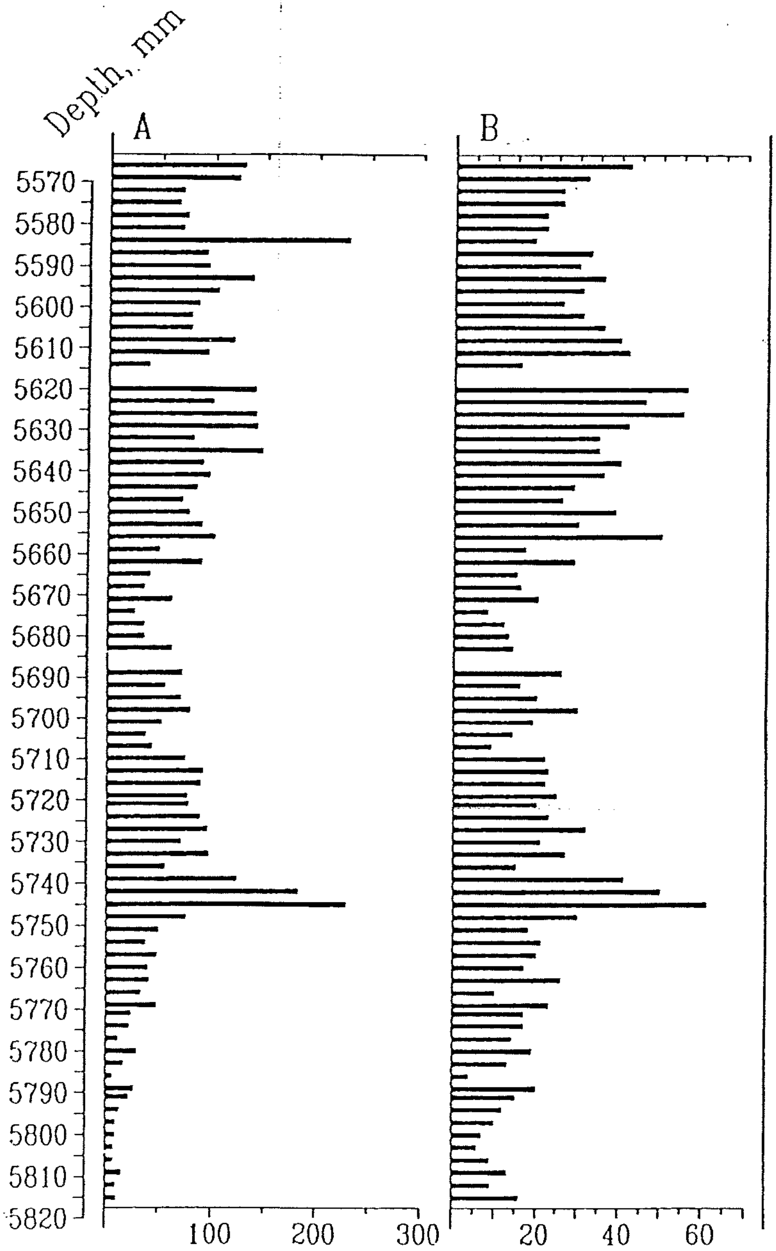

Figure 2. Charcoal frequency in the studied sediment core: A – number of microscopic charcoal pieces; B – area of counted charcoal pieces, μm^2.

(or constant influx from the watershed). Maxima repeat at intervals of about 100–140 years, a recurrence interval for forest fires which has been recorded elsewhere in the boreal zone of N. Europe (Tolonen, 1983; Sarmaja-Korjonen, 1992). As our reconstructions demonstrate, the forest type in the studied area has remained almost unchanged and the sum of precipitations was higher about 6000 BP than today (Punning and Koff, 1996). This allows us to assume that the number of natural forest fires was also close to the contemporary one and the charcoal peaks in Figures 2a,b really reflect the frequency of fires.

Journal of Paleolimnology 18: 33–44, 1997.

The landscape factor in the formation of pollen records in lake sediments

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Key words: landscape development, paleoecology, pollen influx, lake sediments, Estonia

Abstract

Comprehensive paleobotanical and geochemical methods have been used to study the relationship between the spatial scale of landscape development and values of pollen influx to lake and bog sediments. The spatial-temporal history of the four lakes and a bog was established in NE Estonia and pollen analyses of their sediment were made. It was found that the influx of total arboreal pollen directly corresponds with the sizes of the sites studied, and varies with their expansion or reduction.

Introduction

Lake sediments provide a valuable record for studying the variation in the physical environment and the dynamics of past ecosystems. Therefore, many projects and scientific papers are devoted to the reconstruction of past environment on the basis of paleolimnological data. The aim of the present paper is to attempt to find the spatial scale of catchment area for pollen deposited into the sediments of lakes of different sizes.

Pollen analysis has been the basic method for reconstructing vegetational change on different spatial scales. Being dependent on orographic, hydrological, edaphic, climatic and anthropogenic factors, vegetation is a synthesis of the ecological conditions characteristic of a particular area. The establishment of the relationhips between vegetational changes and pollen spectra enables one to describe the past vegetation.

The main difficulties in applying pollen data to paleoecological reconstructions are connected with their interpretation. One problem is the complicated nature of the processes which determine the formation of individual pollen spectra. A theoretical basis for distinguishing the influence of different pollen sources is the concept of the spatial-temporal geographical system (Birks & Birks, 1980; Delcourt et al., 1983; Berglund, 1991; Punning, 1991; Chambers, 1993).

In the reconstruction of past vegetation, spatial scale is a critical factor (Prentice, 1985; Sugita, 1993; Jackson, 1990; Jackson & Wong, 1994; Janssen & Birks, 1994). The spatial resolution resolvable by each fossil assemblage is determined by the original source area from which the organisms are derived, their mechanism and distances of transport, and the depositional environment within which they are entombed. Jacobson & Bradshaw (1981) have integrated models of both the mechanisms of transport (Tauber, 1965) and the nature of source area (Janssen, 1966) in order to produce a contemporary example for the paleoecological interpretation of fossil assemblages of pollen grains and spores. There presently exist different opinions about the relationships between the pollen source area and influx values. For example, Jackson (1990) has found that pollen source areas of small lakes are larger then predicted by different models.

What often aggravates the problem is the environmental variability of ecosystems in space and time, and the tolerance and inertness of ecosystems to influencing forces. As the development of natural conditions is determined, it is necessary to choose a corresponding spatial system for the description of processes on different levels. In practice this means that for separating the global, regional, extralocal and local impacts on the state and dynamics of the ecosystem, one must operate with a certain spatial-temporal natural system (Punning, 1994).

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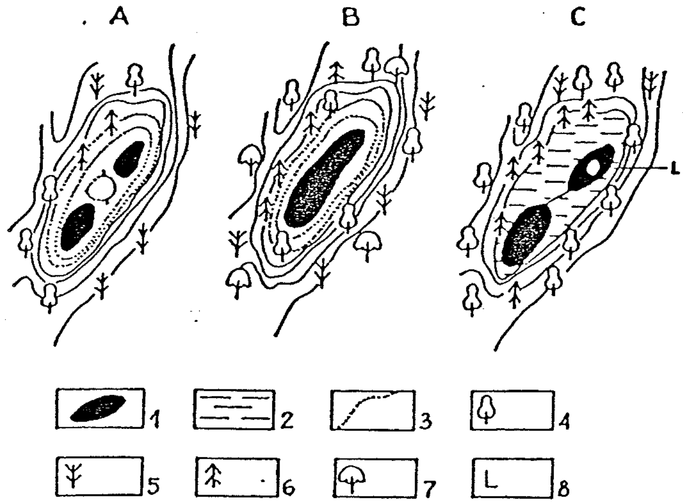


Figure 4. Development of Linajärv. A. 6000 BP; B. 4000 BP; C. modern. 1 – lake; 2 – bog; 3 – isolines below modern surface; 4 – *Betula*; 5 – *Pinus*; 6 – *Picea*; 7 – broad-leaved trees; 8 – study site.

Table 1. Characteristics of the sites studied

Site	Time span (kyr)	Size	Area (ha)	Max.thickness of sediments (m)	Max. depth of water (m)
B. Liivjärve	9.7–0	2000 × 6000	1200	6.4	–
L. Martiska	9.5–0	350 × 100	3.5	5.2	6.0
L. Linajärv	9.2–0	100 × 70	0.7	5.7	7.3
L. Konsu	10.0–0	1500 × 750	112.0	6.0	7.0
L. Ümarjärv	9.0–0	140 × 140	2.0	7.2	7.0

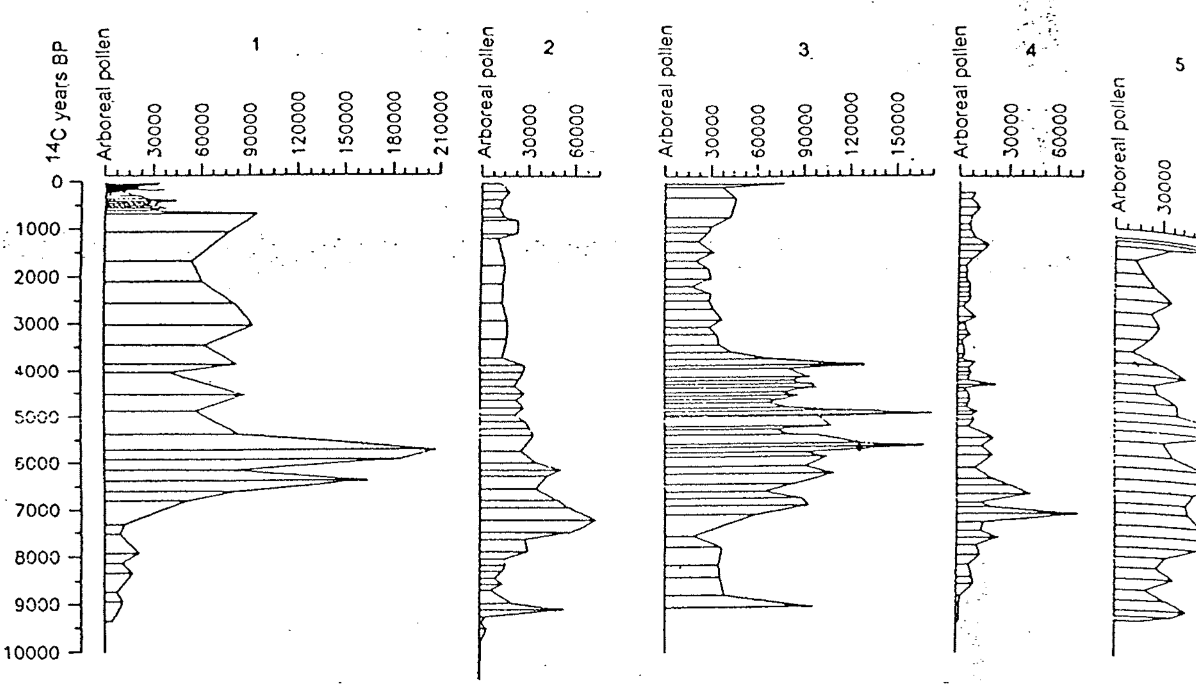
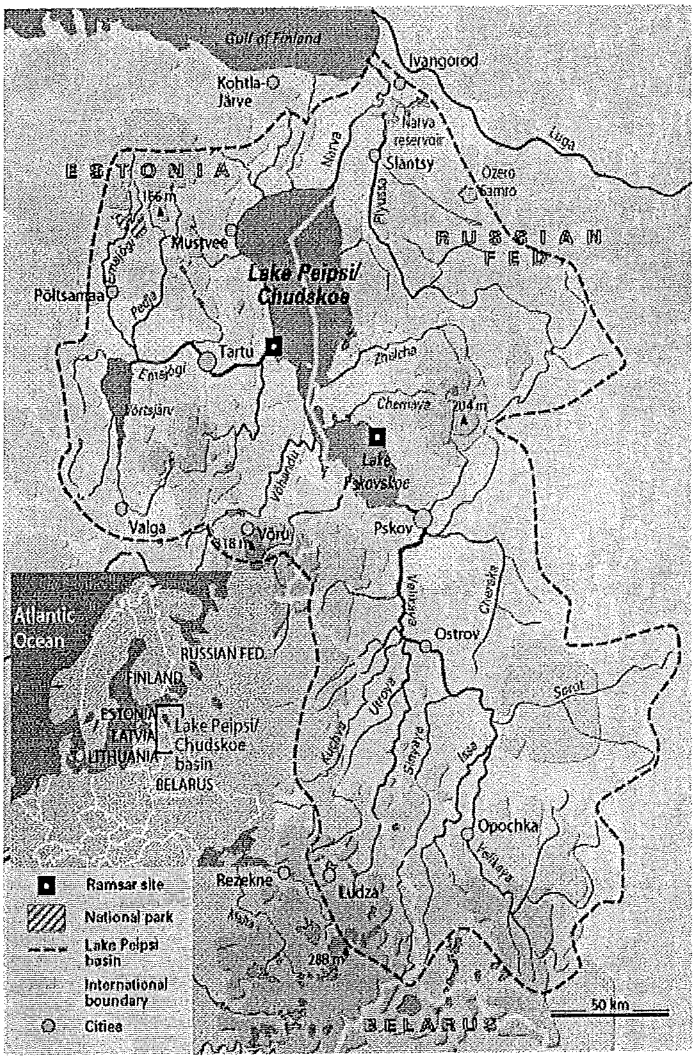


Figure 7. Total AP influx curves for profiles studied. 1 – Linajärv; 2 – Konsu; 3 – Ümarjärv; 4 – B. Liivjärve; 5 – L. Martiska.

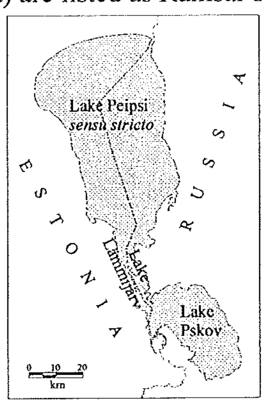
LAKE PEIPSI

Galina Kapanen, Institute of Ecology

Fig. 1. Location map of Lake Peipsi. Map prepared by AFDEC. Source: UNESCO–WWAP.



Lake Peipsi (3555 km^2) is the fourth largest lake in Europe after Ladoga, Onega and Vänern with respect to surface area. The lake consists of three parts: the largest and deepest northern part L. Peipsi *sensu stricto,* the middle strait-like part L. Lämmijärv and the southern part L. Pskov . The largest rivers are the Velikaya, the Emajõgi, the Võhandu, and the Zhelcha. The catchment basin of L. Peipsi, which extends from 59°13′ to 56°08′ N and from 25°36′ to 30°16′ E, is a generally gently undulating glaciolacustrine or till covered plain. The surface area is 3555 km^2; its average depth is 7.1 m, maximum depth is 15 m and the residence time of water is about two years (Jaani et al., 1998; Jaani & Raukas, 1999). The L. Peipsi wetland areas Emajõe Suursoo (Estonia) and Remedovsky (Russia) are listed as Ramsar sites.



Morphometric data on Lake Peipsi (at water level 30 m a.s.l.)

	Peipsi *s.s.*	Lämmijärv	Pskov	Peipsi
Area, km^2	2611	236	708	3555
Volume of surface area, %	73	7	20	100
Volume, km^3	21.79	0.60	2.68	25.07
% of total volume	87	2	11	100

Depth mean, m	8.3	2.5	3.8	7.1
maximum, m	12.9	15.3	5.3	15.3
Length, km	81	30	41	152
Width mean, km	32	7.9	17	23
maximum, km	47	8.1	20	47
Length of shoreline, km	260	83	177	520
Distribution of total length, %	50	16	34	100
Distribution of the aquatory between Estonia and Russia, %	55/45	50/50	1/99	44/56

Sources: Соколов, 1983; Jaani et al., 1998.

Significant recent changes are due to fluctuations in water level of up to 3.04 m in the past 80 years (Tavast & Raukas, 2002). The surface area may vary by 850 km^2 and the water volume by 11.15 km^3 (Соколов, 1941, 1983; Eipre, 1964; Jaani & Raukas, 1999). The water level of L. Peipsi reveals periodic variations with cycles of 18–33 years (Jaani, 2001a).

The water quality of the L. Peipsi basin depends on natural processes and human activities. Intensive anthropogenic eutrophication of L. Peipsi started in the 1970s (Starast et al., 2001). The pollution load was the largest at the beginning of the 1980s due to intensive human activity in the catchment area. Because of inefficient use of fertilisers and improper manure handling during the Soviet period, agriculture caused high emissions of nutrients (total N, N_{tot} , and total, P_{tot}) into rivers and lakes and subsequent eutrophication problems. During the 1990s the pollution load coming with the effluent decreased significantly as a result of the improved water protection measures owing to progress in wastewater treatment and decrease in diffuse pollution from agricultural lands (Loigu et al., 1999; Blinova, 2001). However, judging by the state of the biota, the trophic situation in the lake has not yet improved (Kangur et al., 2002).

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ENVIRONMENTAL CO-OPERATION IN THE TRANSBOUNDARY LAKE PEIPSI BASIN DURING THE LAST 10 YEARS

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Introduction

When the political boundaries separate a natural resource system, numerous barriers on the way to effective ecosystem management are ever more profound. More than 10 years after the disintegration of the Soviet Union and peaceful restoration of Estonia's independence in 1991, relations between two neighbours – the Russian Federation with its population of approximately 150 million and Estonia with its population of only 1.4 million – still have considerable room for improvement. The drainage basin of Lake Peipsi, situated on the border of Russia and Estonia, is a good example of establishing a transboundary water environmental regime (Fig.1). The geographical location of the lake established fairly strict restrictions on habitation and boundaries between states. In addition to Russia Estonia shares freshwater resources with Latvia.

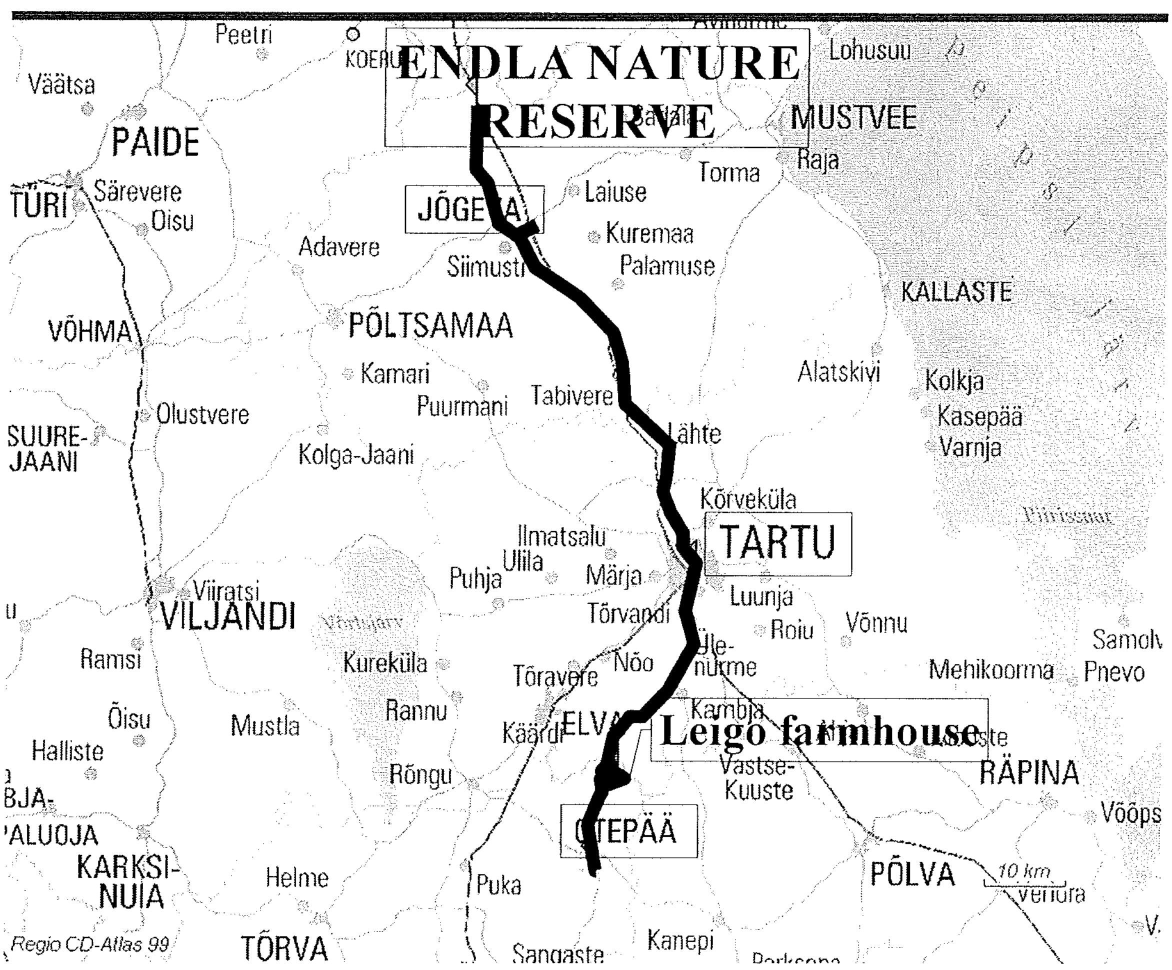
Estonia is going to enter the European Union (EU) in May 2004. After that Lake Peipsi will become a transboundary water body shared by a EU member country and a non-EU country – Russia. Nowadays Estonia actively participates in the accession process into the EU with complex implementation of water policies as well as the EU water policies for transboundary waters. As part of this work the Estonian Water Act has been harmonised with the requirements of the EU Water Framework Directive (WFD).

The principal objective of the WFD is to restore all natural waters to good status. The WFD will integrate the current approaches into the classification systems for the "ecological status" where eutrophication plays an integral part.

Tuesday
24 August

Endla Nature Reserve - Tartu University - Tartu Botanical Garden - Otepää Landscape Reserve

Tuesday, 24.08.04



ENDLA NATURE RESERVE

By Kai Kimmel

The Endla Nature Reserve in central Estonia was established in 1985 and covers 7591 ha. The aim of the reserve is to protect the best preserved central part of the large Endla mire system (total area *ca* 25 000 ^{2} km) on the southern slope of the Pandivere Upland. It is one of the most important freshwater systems in Estonia representing a complex of karst springs, rivers, freshwater lakes, mires and swamp forests supporting rich diversity of species.

The diverse surface relief and pressurised ground water have led to the formation of mire complexes of different ages and appearance, seven of which are included in the nature reserve. Moraine ridges enliven the bog and forest landscapes and lakes and ten groups of copious springs rise at the western edge of the mire complex. In the heart of the nature reserve there are neither roads nor bridges, the surest way of getting anywhere is by boat. In 1997 Endla was listed as internationally important wetland (Ramsar) site.

Bogs

Rivers, boggy forests and Lake Endla separate seven bog complexes, which define the character of the Endla NR. The representative bogs with bog pool systems in the eastern part of the nature reserve are among the oldest in Estonia. The largest are the Linnusaare Bog (1200 ha) and Toodiksaare Bog (1100 ha). Oblong Kanamatsi Bog is pressed between the rivers. Various *Sphagnum* mosses dominate in the bog creating an environment that is poor in nutrients and therefore only about 20-30 vascular plant species can survive. The plant communities are mosaic as higher sites interplace with low watery hollows and bog pools. The bog water is acid, containing abundant organic matter and limited amount of minerals but the water is perfectly safe to drink.

Springs

The western part of the Nature Reserve is remarkable for the number and size of its springs. The water originates from the Pandivere Upland, where creviced karsted limestone lay under thin surface. Over 30 large springs have been counted in the Nature Reserve; the number of smaller trickling fonts is impossible to determine. The springs are grouped together. The Metsanurga site with its thirteen springs on both sides of the Oostriku River is the largest. The deep funnels of Vilbaste springs bubble by the Võlingi Stream. The Võlingi and Oostriku springs are among those of the highest flow rate in Estonia. The Sopa Spring with its 4.8-metre depth is the deepest. The Rummallikas, one among the Haava Springs has given the name to a bog. The Värviallikas is noteworthy, since its water and surrounding peat contain a large amount of poly-metallic ores due to a hydrogeochemical anomaly. The temperature of the refreshing spring water is between two to eight degrees Celsius all year round.

Lakes

The lakes of the nature reserve are remnants of the ancient Great Endla that are very slowly overgrowing today. Human activities have played their role in the process. The local estate owner ordered a 5 km long canal to be dug from Lake Endla through the bog and Lake Sinijärv to the Põltsamaa River for meliorating the swampy meadows of the estate in 1872. The canal was dredged in 1950 and that lowered the water table of the lakes a second time. In 1997, a strong dam of local stone was constructed that now regulates the water level and hinders the overgrowing of lakes Endla (287 ha) and Sinijärv (42 ha). All six lakes provide habitats to numerous living organisms and bring variety to the bog landscape.

Plants

453 species of vascular plants and 165 of moss species (among them 25 *Sphagnum* species) have been noted. 29 vascular plant species are listed as protected (II and III category), among them 18 species of wild orchids. Most noteworthy are rare and endangered Bog Orchid, White Adder´s Mouth, Coralroot Orchid, Lady´s Slipper, Arctic Bramble, Selaginella. Water Lilies decorate the lakes. The evergreen Fir Club Moss is abundant in shady forests. In May, the shores of waters turn lilac as the Swamp Violet is in bloom.

Birds and mammals

The bird fauna includes 182 species, 153 of them are breeding birds. Lake Endla is one of the richest bird lakes in Estonia: up to 9000 nesting pairs have been counted here. Ducks terns, seagulls, grebes, cranes, harriers, and lot of other bird's nest in reed-beds and floating islands. In spring and autumn migration period, large flocks of geese and swans stop in Lake Endla and Sinijärv. Capercaillie lives in old pine forests; the Black Grouse and Hazel Grouse are quite common. The Endla Mire is a stronghold for eagles. If lucky, four different species of eagles can be observed within a day. The Golden Eagle is the bird of bogs. The Lesser Spotted Eagle nests in bog forests. The Osprey and White-tailed Eagle feed on the lakes. 42 species of mammals occur in the Nature Reserve. The area belongs to the best habitats in Estonia for big carnivores such as Lynx, Wolf and Brown Bear. The abundant water favours beaver and otter.

MIRE RESEARCH TRADITIONS IN ENDLA NATURE RESERVE

Kai Kimmel

Kimmel, K. 1998. Mire research traditions in Endla Nature Reserve. - Estonia Maritima 3: 179-186.

The essential part of scientific research into mires in Estonia has been performed in the Endla mire system, Central Estonia. In 1985, Endla Nature Reserve was founded to preserve the site as a virgin mire complex typical of Estonia and as a classical research area. In this paper, the development of mire research carried out in Endla mires since 1910 is reviewed. Five periods are distinguished to describe the main research activities.
Key words: Estonia, Endla mire system, mire science, history

1. Introduction

Mires are estimated to cover 22% of Estonia's territory. Nowhere in the European cultural region can one find mires of such size, containing such a diversity of wildlife, and which are so well preserved.

Although the first lecture course in mire science (telmatology) was held by J. Klinge at Tartu University in 1879, systematic research of Estonian mires started in 1910, when Tooma Experimental Mire Station at the eastern border of the Endla mire system was established. It must be mentioned that the mires of Endla were visited by some of enthusiastic naturalists who were mainly interested in mire vegetation (K.E.v. Baer, A. Bruttan, G.K. Girgensohn, A. Bunge) as far back as in the 19th century.

Since 1910 the fens and bogs of Endla mire system have been a research field for several research institutions and for most of Estonian mire scientists. The objective of research has changed - provisional interest in agricultural utilisation of mires has been replaced by interest in evaluation and preservation of this type of wetlands. A huge amount of data about the structure, genesis, ecology and wildlife of bogs has been gathered. The long tradition of research was one of the main reasons why the area was declared nature reserve in 1985.
In general, five periods of mire research at Tooma and in the bogs of the Endla mire system can be distinguished:

1. 1919-1914, establishment of a specialised mire research station at Tooma;
2. 1921-1944, fen research catalysed by agricultural interests and mire studies based on pollen analysis carried out by P.W. Thomson;
3. 1944-1960, the most intensive research period with several research groups involved;
4. 1960-1985, detailed studies of the features of the development of mires;
5. from 1985 to nowadays, the research activities co-ordinated by Endla Nature Reserve.

The results of the comprehensive agricultural applied research of mires (mainly fens) performed at Tooma are not treated in this paper. Only geological, hydrological and ecological studies are reviewed and selected references are given.

2. 1910-1914: the foundation of Tooma Mire Experimental Station

At the end of the 19th century the agricultural utilisation of Estonian peatlands started to develop rapidly. In 1908, the Baltic Peatlands′ Improvement Society was founded in Tartu for the purpose of organising the agricultural use of peatlands in the region. The Tooma Mire Experimental Station at the eastern border of the Endla mire system subordinated to it was set up in 1910. Before starting practical drainage and cultivation experiments, the territory of the station (a part of Männikjärve bog and the near-by fen area) was thoroughly investigated, supervised by the head of the station A.v. Vegesack. 53 boreholes were drilled. That was the first detailed complex study of fen and bog vegetation (Precht 1913), peat stratigraphy and agrochemistry (Vegesack 1913) carried out in Estonian territory.

The activities of the station were discontinued during The First World War. A.v. Vegesack who had become the leading mire scientist of the period left Estonia.

3. 1921-1944: fen studies, first pollen analyses

3.1. Fen studies at the Tooma Mire Experimental Station

During that period the re-established Tooma Mire Experimental Station directed by L. Rinne continued to be the centre of field experiments and research work. The main objective of the station was to study the prospects of the agricultural use of Estonian fens. The station performed peat soil surveys in various parts of Estonia in order to assess the distribution of fens and their suitability for agricultural reclamation. The botanical composition, decomposition degree, physical properties and main chemical characteristics of peat layers of 69 fens were analysed. On the basis of this research, L. Rinne received his doctoral degree in 1928 at Tartu University.

3.2. P.W. Thomson, a pioneer of pollen analysis in Estonia

The most outstanding mire scientist of the period, P.W. Thomson worked as a botanist at the Tooma Mire Experimental Station in 1923-1939.

Thomson, a botanist and geologist, was one of the founders and introducers of the palynological research method (a microbotanical study of peat and lake sediments in order to determine the age of different layers by means of analysis of the pollen and spore associations contained in them) in the world. By means of this method he investigated Estonian bogs (Thomson 1926), determined the age of different archaeological finds and studied the evolution of the baltic Sea. He compiled the first reasonably complete stratigraphic scheme for the Estonian Holocene and generalised the development of Estonian nature after the ice retreat. He investigated the peat-layer of more than 30 Estonian mires (among them the Endla bogs) and described the main tendencies of their development (Thomson 1939). Also, he was the first to describe the differencies between the West and East Estonian bogs. After defending his PhD degree at Riga in 1927, he became a private docent of geology and palaentology at Tartu University (lecture courses about telmatology, peatland geology, pollen analysis and the Holocene history of Estonian forests). He delivered lectures also in Köningsberg University and found time (1928-1932) to teach several natural disciplines (including botany and geology of mires) at the Tooma School of Peatland Cultivation and Soil Improvement.

In 1923, having just started his mire studies, P.W. Thomson held the first talk about the necessity of nature protection in mires. P.W. Thomson became an internationally appreciated specialist in paleobotany during his Tooma-period. In 1939 he left for Germany where his interest focused on the problems of brown coal geology. His palynological studies are of permanent value. In 1995 The Estonian Nature Conservation Society opened a memorial plaque in honour of P.W. Thomson at Tooma, on the wall of the former schoolhouse for peatland cultivation where now the centre of the Endla Nature Reserve is located.
During the same period, some naturalists interested in botany (T. Lippmaa), bog bird fauna (M. Härms, E. Kumari) and bog insects (H. Kauri) shortly studied the area. In 1938, a Mire Research Institute was established on the basis of the Experimental Station, the aim of which was to continue more extensive research work. The idea was realised only after the Second World War.

4. 1944-1960: the most intensive research period with diverse scientific activities

4.1. The first peat inventory carried out by the specialists of the research institute at Tooma

In addition to agricultural applied research, one of the large research projects of the several times reorganised mire research institute was the inventory of Estonian mires for agricultural utilisation purposes. The work was carried out by the team of specialists of the mire research sector (later group) (A. Truu, H. Kurm, K. *Veber et al.*) during 1947-1960. Nearly 65% of Estonian mires were investigated. As a result of the comprehensive studies, the map and statistics were compiled concerning mires in Estonia (Truu, Kurm and Veber 1964). During the period, the geology and genesis of the Endla mire system were thoroughly studied as well (Veber 1960, 1974).

In 1960, a summary of the 50-year-long investigation into mire culture at Tooma was published. In the same year the mire research group was moved from Tooma to Saku and mire studies died out gradually.

4.2. Multidisciplinary, mainly biological bog research
During several years (1947-1953) the ecosystems of Endla bogs were studied by a team of young researchers in order to characterise the main features of bog landscape. The report of the complex ecological studies in 1957-1960 was published in a series of articles entitled "On investigation of the bog landscape of Endla" in Yearbooks of the Estonian Naturalists Society (vol. 50, 51, 52). The aspects of bog wildlife and environment studied were as follows: the geology, hydrography and genesis (K. Veber), plant cover (M. Kask), the flora of vascular plants and the fauna of vertebrates (V. Masing), spider fauna (A. Vilbaste) and insect fauna (V. Maavara), algae flora (M. Pork), bog plant communities and species relationships in them (V. Masing), the influence of the lowering of the water table of Lake Endla to the surrounding vegetation (L. Viljasoo), and also the hydrochemistry of bog lakes (H. Simm) and peculiarities of bog microclimate (H. Viigimäe). These intense studies of Endla bogs laid the basis for the internationally appreciated research into the development and structure of bogs carried out later by V. Masing and were probably one of the main reasons that he bacame an enthusiastic fighter for mire conservation.

4.3. The foundation of Tooma Hydrometeorological Mire Station

In 1950 Tooma Hydrometeorological Mire Station was founded. A stationary observation network was established in Männikjärve and Linnusaare bogs in order to observe several hydrological phenomena of bog massifs. It was an important event, as water plays a decisive role in the origin and development of mires. The station belonged to the network of hydrometeorological mire stations of the former Soviet Union, where at that time in contrast to the fragmented western effort, a readily discernible school of mire hydrology was established. On the basis of the observation data gathered at the stations several papers were published mainly by scientists of the Department of Mire Hydrology of the State Hydrological Institute at Leningrad, the most important of them K. Ivanov's monograph (1957) about mire hydrology. An english edition of the book "Water movement in mirelands" was published in 1981 (Ivanov 1981). This was the first treatise appearing in the English language to deal with the general hydrology of peatlands. It was stressed that this was the most advanced work on the hydrological aspects of mire ecology having appeared so far, and it should be studied by anyone wishing to take the subject further (Ingram 1983).

The observation program of Tooma Mire Station (now belonging to the Estonian Meteorological and Hydrological Institute) has been quite stable during nearly fifty years. It consists of direct measurements of all components of the bog water balance - precipitation, evapotranspiration, discharge, groundwater level, bog water level, and microclimate studies of the bog and on the mineral ground. The results are published in a series of yearbooks.

5. 1960-1985: detailed studies of bog ecology and natural dynamics

The studies of Endla bogs during that period were focused on getting information on ecology, structural organisation, and natural dynamics of mires. M. Ilomets started research into the peat moss growth and productivity of Sphagnum communities and the rate of peat accumulation (Ilomets 1982). Also the dynamics of development of bog hummock plant communities and the cyclical nature of the development of bogs (on the basis of palaeobotanical analyses of peat layer and radiocarbon dating) were studied by him (Ilomets 1984).

V. Masing generalised his results of the investigations carried out during three decades in the Endla mire system and also in other sites concerning the structure of the plant cover of Estonian bogs (Masing 1982).

On the basis of the observation data of the hydrometeorological station the peculiarities of mire water regime were described (Mets *et al.* 1972). Several characteristic features of bog water balance, temperature regime and some general problems concerning the growth and development of bogs and the formation and development of bog pool complexes were studied by the head of the station L. Mets (Mets 1982).

At the end of the 1960s, mire protection began to receive international attention. Under auspices of the International Biological Programme (IBP), the project Telma was initiated to specify more accurately the criteria for mire protection areas. V. Masing suggested that Endla mires should be taken under protection as a thoroughly studied peatland site of international importance (Masing 1970). One of the most important criteria was that the site had been the scene of a detailed research and was well documented.

6. From 1985 to nowadays: the Endla Nature Reserve co-ordinating bog research

One of the main objectives of the established nature reserve set by the basic regulation is to be the centre of a prolonged scientific research into the development of mire ecosystems. Realising the task is supported by several advantages:

- diverse bog complexes of high conservation value;
- hydrometeorological mire station as a monitoring unit studying the long-term changes and guaranteeing basic information for different research programs;
- long research traditions;
- huge data base;
- contacts and co-operation with various research institutions and mire scientists.

It is remarkable that Viktor Masing who has enthusiastically investigated this region has educated a number of students and roused their interest in mire science. His students and his students'students continue the research into Endla mires. Several studies should be mentioned. V. Masing generalised his studies of many years on raised bogs concerning an exceptional tree growth due to additional nutrition brought in by birds and interbog inflows (Masing 1988). M. Ilomets compared the spatio-temporal pattern of bog communities on the basis of microstratigraphic studies in order to clarify some regularities of vertical distribution of *Sphagnum* and other moss communities in connection with a detailed study of bog ecosystem development (Ilomets 1988). Heavy metal contents in *Sphagnum*, acrotelm and peat were investigated (Ilomets *et al.* 1992) in Männikjärve bog.

Estonian leading mire hydrologist, A. Loopmann, has described and explained the runoff regime from mires, while special attention is given to the data collected at Tooma Hydrometeorological Mire Station (Loopmann 1996).

In recent years the wetlands group of the Institute of Ecology has concentrated on investigating the present state and development of mire ecosystems during Holocene. One part of their research is done in the Endla mire system. In 1994-1996 M. Ilomets participated in the EC-granted project "Impact of nitrogen deposition on the carbon balance in peatland ecosystems". The main aim of the project was to study the possible impact of agriculture-induced atmospherical nitrogen contamination on the growth and productivity of *Sphagnum*. The field experiment in Estonia was conducted in Männikjärve bog. E. Karofeld has studied the formation and development of bog hollows (Karofeld 1995). Investigations into the methane emission from bogs (a joint projects with specialists from Marburg University) are in progress. Ü. Kasemetsa has started with mathematical modelling of long-term hydrological monitoring data of Tooma Hydrometeorological Mire Station to elucidate the formation of bog water table regime (Kasemetsa 1995).

Some other interesting research projects are in progress - the dynamics of bog bird fauna (A. leito), bog microfungi as an indicator of pollution (T. Ploompuu) and others.

During this period the research work has become more international, especially due to the contacts with german mire scientists (Deutsche Gesellschaft für Moor- und Torfkunde). Evaluation of research traditions and promotion of further investigation into mires is continuously one of the duties of Endla Nature Reserve, a Ramsar site since 1997.

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Pollen influx into Tauber traps in Estonia in 1997–1998

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Abstract

Modern pollen trapping data, obtained in the years 1997 and 1998 from 32 modified Tauber traps in different landscape regions of Estonia, are discussed. Preliminary analyses have revealed great variability of pollen influx values. The influx of arboreal pollen (AP) in 1998 was in general three to four times higher than in 1997. In both years, *Betula* and *Alnus* pollen dominated, accounting for up to 70% of total AP. The share of non-arboreal pollen (NAP) was much higher in pollen traps than in samples from lake and bog sediments and this reflects the influence of very local vegetation. Cerealia-type pollen influx values are closely correlated with the distance of the study site from the nearest field and also show the existence of some background values in the atmosphere. © 2001 Elsevier Science B.V. All rights reserved.

Keywords: pollen influx; Cerealia; Estonia; pollen trap; deciduous-coniferous forest

1. Introduction

The relationship between pollen spectra and vegetation has been discussed since the introduction of pollen analysis (Erdtman, 1921; Aario, 1932). Different methods have been used to elucidate this problem, including the study of surface samples from bogs and lake sediments (Davis, 1963; Janssen, 1966; Andersen, 1970; Davis et al., 1973), moss samples (Gaillard et al., 1992, 1994) and pollen traps (Tauber, 1974; Hicks, 1985, 1992).

In Estonia, samples from the surface of sediments in Lake Peipsi were studied by Pirrus (1981). Moss samples from the surface of a small kettle hole (1.62 ha) in southern Estonia (Punning et al., 1995) were studied to investigate local variations in the pollen spectra. As a result, a large range of frequencies of *Picea* pollen in surface samples (from 2 to 25%) was established. An experiment trapping pollen on glycerine-covered glass plates (Koff and Punning, 1985) demonstrated that the pollen of *Betula* and *Pinus* appeared in different parts of Estonia at least 2 weeks before these tree species began to flower, indicating the presence of long-distance transported pollen. Investigations carried out on Nigula bog (Koff, 1997) have shown that pollen spectra may differ widely even over rather small distances depending on the patchy nature of the landscape (i.e. varying distance from an island of mineral soil covered with broad-leaved trees).

Analysis of moss samples from north-eastern Estonia (Koff, 1991) showed that, in the main, the composition of the pollen assemblages reflected that of the forest. Comparison of the results with forest assessment data (Koff, 1994) suggested that the pollen spectrum is most representative of the local vegetation. In general, the results of the analysis of modern pollen spectra in Estonia agree well with current knowledge of pollen distribution (Tauber, 1965; Jacobson and Bradshaw, 1981; Prentice, 1985; Jackson, 1990). However, as these studies are based on percentage data, they give little information about the abundance of species in local vegetation. Pollen

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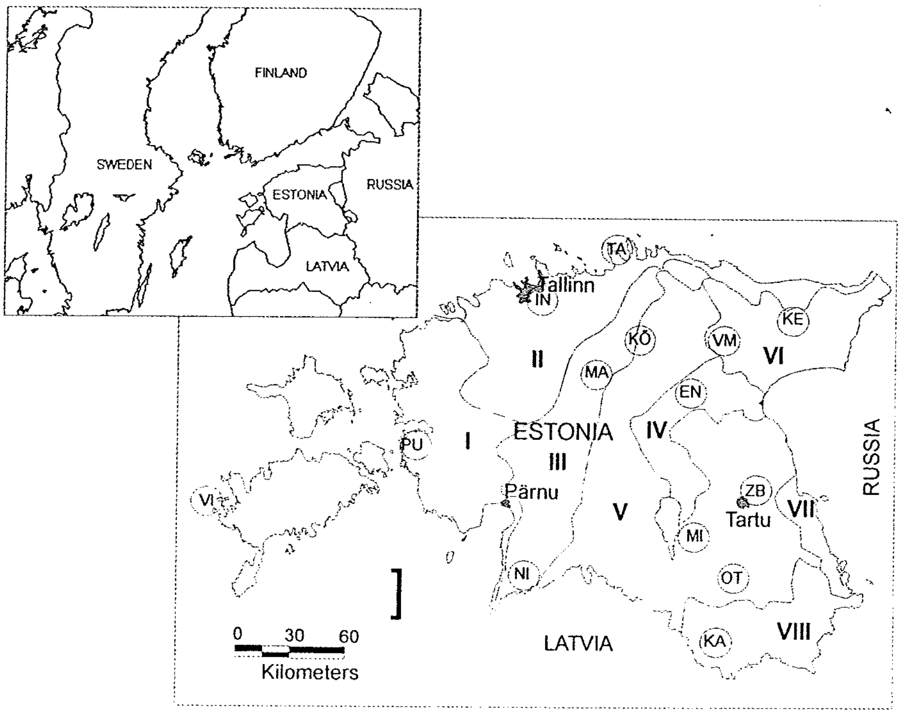
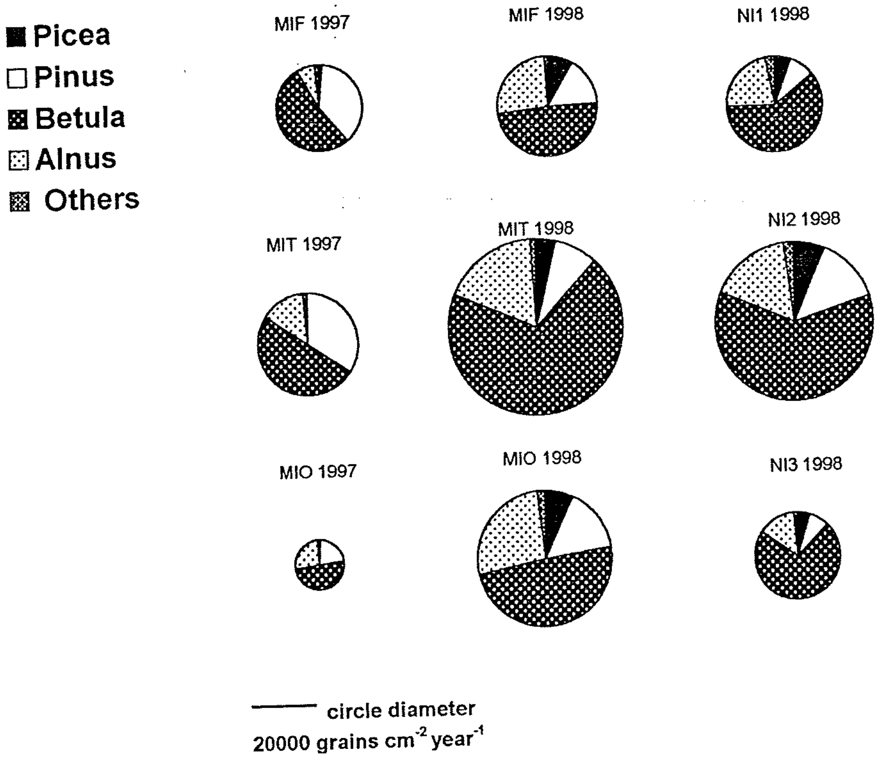


Fig. 1. Location of the study sites. Site codes are given in Table 1. Geobotanical division is given after Laasimer (1965): (a) West-Baltic geobotanical sub-province; (b) East-Baltic geobotanical sub-province. I—VIII, geobotanical districts: I, West Estonian meadows and forested meadows; II, North-west and North Estonian dry and fresh grasslands; III, Intermediate Estonian peatbogs and swamp forests; IV, Floodplain grasslands and mires of the Pedja river basin; V, East and Middle Estonian boreo-nemoral forests; VI, North-Estonian peatbogs and swamp forests; VII, Floodplain grasslands of the river Emajõe on southwestern coast of L. Peipsi; VIII, South-East Estonian sandy pine forests.

influx values, i.e. the number of pollen grains deposited on the unit of the surface area at a given time can provide more objective information (Davis, 1976; Davis et al., 1980; Hicks, 1997).

Within the framework of the European Pollen Monitoring Programme, 32 pollen traps of a modified Tauber-design were exposed in different landscape regions of Estonia. More than 40% of Estonian territory (45,000 km^2) is covered with forests, 22% is occupied by mires and cultivated land makes up about 24%. The main forest-forming species in Estonia are as follows: pine (*Pinus sylvestris*), 41%; birch (*Betula pendula* and *B. pubescens*), 29% and spruce (*Picea abies*), 23%. Alder (*Alnus incana* and *A. glutinosa*) at 6% and aspen (*Populus tremula*) at 2% occur to a lesser extent. The proportion of oak (*Quercus robur*), elm (*Ulmus montana* and *Ulmus glabra*) and linden (*Tilia platyphyllos*) is insignificant in Estonian forests (Etverk and Sein, 1995). Based on vegetation mapping data, Laasimer (1965) divided Estonian territory into eight large geobotanical districts, which are classified into two sub-provinces of the Baltic geobotanical province. The districts are divided into 13 subdistricts, which, according to the distribution of vegetation complexes, are subdivided into 87 microdistricts. They all are characterised by a complex environment, specific agricultural, forestal and industrial features and density of settlements. This division was used for characterisation of the dominant plant communities around the study sites.

The main aim of the current study was to provide new information on modern pollen influx in different vegetation areas in Estonia and to assess its spatio-temporal variation. The data obtained will be useful for understanding the relationships between changes in pollen influx and vegetation history and relevant to the interpretation of pollen spectra from peat and soil profiles (Hicks et al., 1996).



elative representation (% AP) of main pollen types and AP influx values (grains cm^{-2} yr^{-1}) for three traps from site NI in 1998 and site 997 and 1998.

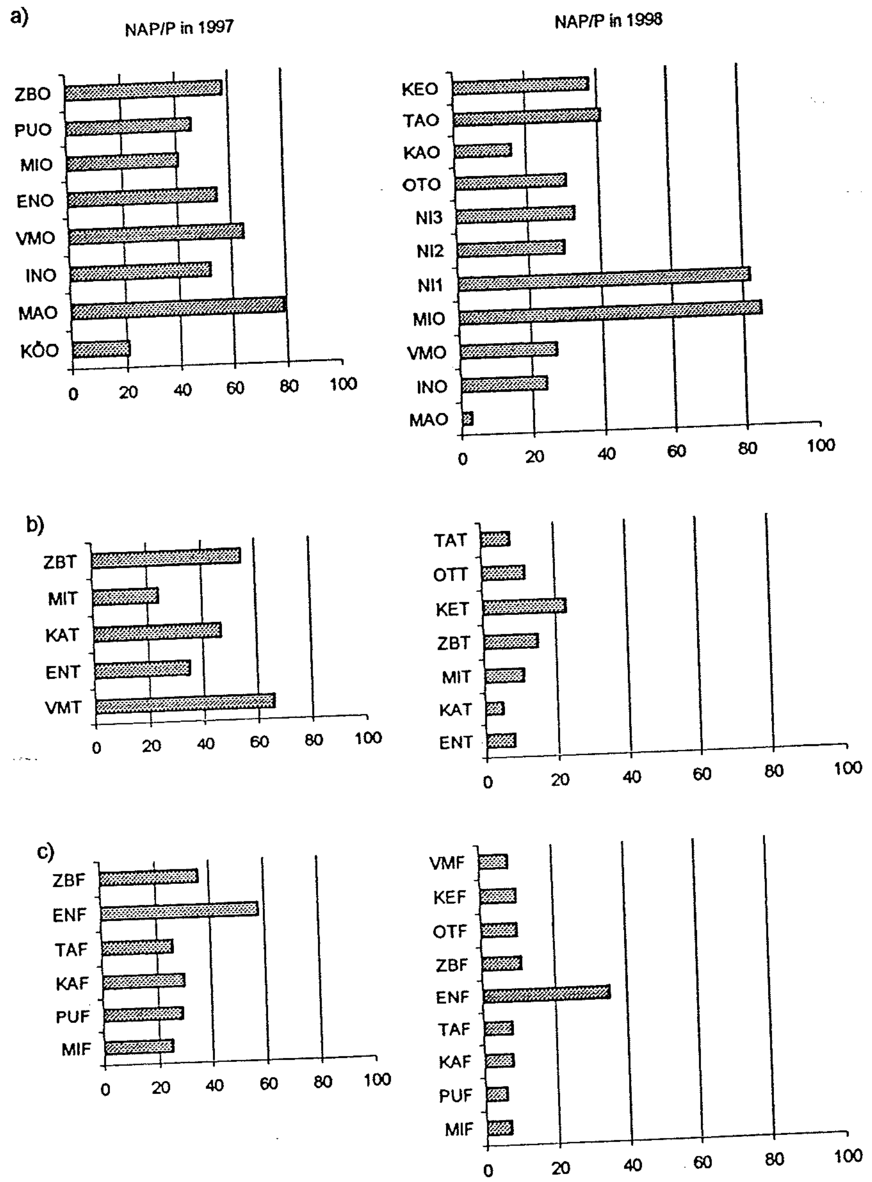
varied from 23,000 to 41,000 grains cm^{-2} yr^{-1}. ay be a result of the complicated nature of near- turbulence at this site and will be discussed the interpretation of the data.

ne other traps (Fig. 1) were exposed in different and places, we could study the temporal and variation in the pollen rain in Estonia. The flux in traps varied remarkably from year to Table 1). In 1998 the AP influx was three to mes higher than in 1997 in all localities and ons (Table 2). Similar differences were recorded al pollen content in one cubic metre of air collected by the Burkard trap in Tartu: 54,600 pollen grains in 1997 and 113,700 pollen grains in 1998 (M. Saar, pers. comm.). In both years *Betula* and *Alnus* pollen dominated, accounting for up to 70% of total AP in 1997 and for as much as 86% in 1998. The share of *Betula* and *Alnus* pollen was greatest in the traps from the transitional zone followed by forest traps and traps from the open area.

For *Picea*, the highest values came from the forest sites and lower values from the transitional zone and open area traps. For *Pinus* the distribution is more even. But their influx values are lower than expected

e pollen influx values (grains cm^{-2} yr^{-1}) in traps at different locations. Ä indicates the factor by which values differ between 1997 and

ype	Open area		Ä (times)	Transition zone		Ä (times)	Forest		Ä (times)
	1997	1998		1997	1998		1997	1998	
	40	2100	52.5	20	2400	120	140	3100	22.1
	4400	2500	0.6	3300	4400	1.3	4400	4200	0.9
	1900	14,400	7.6	5800	24,600	4.2	3600	21,000	5.8
	750	5300	7.1	2000	18,400	9.2	600	6200	10.3
	7200	25,000	3.5	11,300	50,200	4.4	9500	35,000	3.7



The share of NAP in total pollen influx (AP + NAP) in traps: (a) from the open area; (b) transitional zone and (c) forests in 1997 and

NAP) was much higher in 1997 first of all due low numbers of AP (Fig. 3). In general, the of NAP was on average 30% in all traps. That tainly higher than in pollen diagrams from e of lake and bog sediments in Estonia, where s rather low, being usually 5–10% (Koff, 1994; , 1998; Poska and Saarse, 1999). Analysis of data from different trap placements gave an ted result: NAP influx was greater in the open han in the forest traps and the transitional zone. nain pollen types forming the bulk of NAP were: Poaceae, Rosaceae, Compositae, Apiaceae, *Galium*. Apiaceae pollen influx was high in the traps close to the abandoned, formerly cultivated fields and fallows, such as sites NI, OT, KA where this type of pollen formed about 50–60% of the NAP. *Galium*-type pollen was more characteristic of natural grasslands.

When trees have grown at the same site for tens of hundreds of years, the composition of the herb layer may differ very widely in separate years due to length of life cycles, strong competition, or meteorological parameters, primarily precipitation during the

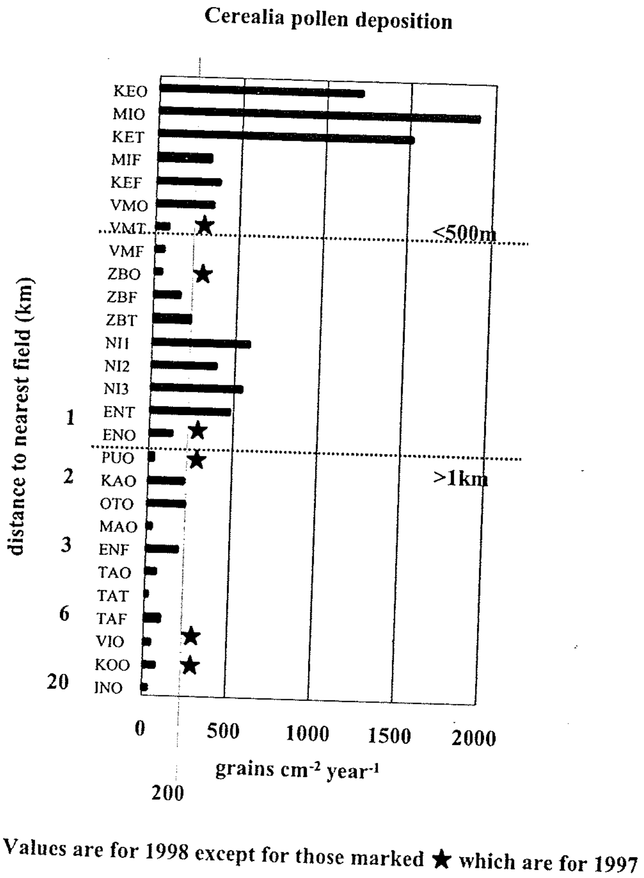


Fig. 4. Influx of Cerealia pollen (grains cm^{-2} yr^{-1}) in Tauber traps in 1997 and in 1998 in relation to distance from the nearest field.

growing season. In agricultural areas it depends on the cultivation system: the type of grain planted in one or another year or the stocking density of the pastures. In several studies and projects (Frenzel, 1992) attention has been paid to the relation between NAP and AP and this has been used to evaluate the area of land surface cleared of forest by human activities. But there is no simple formula for translating the extent and distribution of human settlements or the non-arboreal pollen percentages into absolute surface areas of open land. Therefore, in this study we had great expectations that the data from the Tauber-traps might be valuable for this purpose.

Unfortunately, the hypothesis that land surfaces cleared of forest can be quantified with the help of NAP/AP ratios from pollen traps does not work. Big deviations may be caused by the great influence of local herbaceous vegetation and/or numerous insects occurring in the traps. The question of how to prevent animals and insects from falling into the traps has been under discussion during the EPMP workshop (Hicks et al., 1999) but without any simple solution emerging. At the same time, it is clear that on average the proportion of NAP is higher in traps from open sites (about 30%) and lower in forest and transitional site traps (18%).

Cerealia pollen is regarded as the best indicator of agricultural activities. Due to the rather low number of cereal grains counted in the traps, *Secale-*, *Hordeum-* and *Avena*-types were amalgamated to Cerealia-type. Fig. 4 summarises data on cereal influx for 1998, in some cases where there were no results for that year owing to damage to traps, data for 1997 have been included. Due to the short period of observations no statistical analyses can be made on this limited data set. However, using estimations based on the magnitude of the Cerealia influx in the pollen traps, and distances from the nearest fields, three groups of trap sites can be distinguished:

(1) Traps with more than 1000 grains cm^{-2} yr^{-1} of Cerealia pollen, are directly affected by agricultural activities. For example, trap MIO on grazed grassland lying at a distance of 100 m from a cereal field, and trap KEO, where the trap was situated in the middle of a cereal field. At site KE the Cerealia pollen influx also fell into this category in the transition zone between the field and the forest (trap KET), but fell by a factor of 3 at a distance of 50 m inside the conifer forest (trap KEF). However, no such pattern was observed at site MI. In addition to distance from the source of cereal pollen, such trends are probably also influenced by prevailing wind directions and turbulence.

(2) Traps where Cerealia influx was 200–1000 grains cm^{-2} yr^{-1}. This main group includes the sites where the nearest cereal fields were up to 1 km distant. For example, trap VMO was 300 m away from a cereal field, in an open area, and the influx of Cerealia pollen was 420 grains cm^{-2} yr^{-1}. Pollen traps NI1, NI2 and NI3 were approximately 1 km from the nearest cereal field and here the pollen influx was between 400–500 grains cm^{-2} yr^{-1}.

(3) The influx of Cerealia pollen was less than 200 grains cm^{-2} yr^{-1} at sites lying more than 3 km away from cereal fields.

However, even at a distance greater than 10 km from the nearest cereal fields, at trap KOO, the influx of cereal pollen was 80 grains cm^{-2} yr^{-1}. This appears

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СТРОЕНИЕ И РАЗВИТИЕ ЗОЛЛЯ СИНИАЛЛИКА НА ДРУМЛИНЕ ЛАЙУЗЕ

Среди форм рельефа, осложняющих поверхность крупных Саадъярвских друмлинов (Восточная Эстония), группами встречаются золли — небольшие, преимущественно округлые блюдцеобразные воронки. Они обычно заполнены торфом и/или водой («мокрые» золли), но иногда имеют на дне и склонах лишь делювий мощностью до нескольких метров («сухие» золли).

Наибольшей известностью из золлей Саадъярвского друмлинового поля пользуется относительно крупная впадина-ванна в Лайузе (золль Синиаллика). Она находится на вершинной части Лайузеского друмлина (абсолютная высота 144, относительная — 60 м) в 0,5 км юго-восточнее от шоссе Йыгева—Муствеэ. Золль имеет слегка продолговатую с севера-северо-запада на юг-юго-восток форму, его дно заполнено низинным болотом, поросшим низким березовым кустарником, и лишь в центральной части наблюдается небольшой участок переходного болота со сфагновыми кочками. Площадь заболоченной части золля 11 000 м^2 (130×90 м). В центральной части болота находится легендарный ключ Синиалликас (в переводе с эстонского — голубой ключ). Севернее и южнее Синиалликаского золля цепью расположено множество более мелких как «мокрых», так и «сухих» золлей. Изучение этих микроформ рельефа представляет интерес при выяснении морфогенетических процессов во время деградации материкового льда, а также при выявлении специфики позднеледниковой и раннеголоценовой палеогеографии.

О морфологии, геологическом строении и развитии золлей Саадъярвского друмлинового поля до последнего времени имелись лишь скудные и отрывочные данные. Так сообщалось, что в золле Синиаллика верхний, «водянистый» торф мощностью 3 м подстилается двухметровым слоем «иловатого» торфа (Lillema, 1958).

Летом 1979 и 1981 гг. авторами проведено бурение (рис. 1) Синиалликаского золля. Золль довольно крутосклонный (в среднем 17—18°), его глубина 12—13 м, он почти до краев заполнен торфом. Скважины прошли максимально 11,6 м торфяной залежи, ниже которой в центральной части воронки был вскрыт маломощный (0,7 м) слой пелитового алеврита. На склонах воронки алевритовые отложения имеют мощность от 0,15 м (скв. 4) до 1,8 м (скв. 3) и подстилаются водонасыщенной суглинистой мореной. По краям заболоченной части золля проходит невысокая (до 0,7 м) пахотная терраса, сформировавшаяся в результате техногенной эрозии почв.

Четвертичный покров в самой высокой части друмлина Лайузе представлен в основном супесчаной и суглинистой мореной последнего оледенения, перекрытой либо маломощным слоем (в среднем 0,3—0,4 м) покровной супеси проблематичного генезиса, либо спорадически распространенным флювиогляциальным гравистым песком (до 0,7 м, в основном к востоку от золля). Местами морена на вершине друмлина почти отсутствует (напр., к северу от описываемой впадины), местами же достигает 21 м. Морена подстилается гравийно-песчаными отложениями

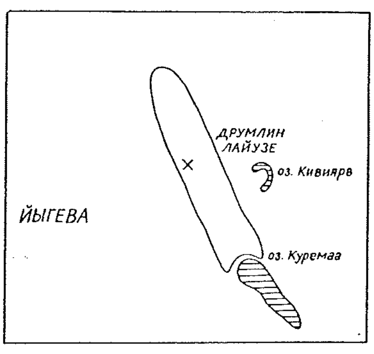

Рис. 1. Схема расположения золля Синиаллика на друмлине Лайузе.

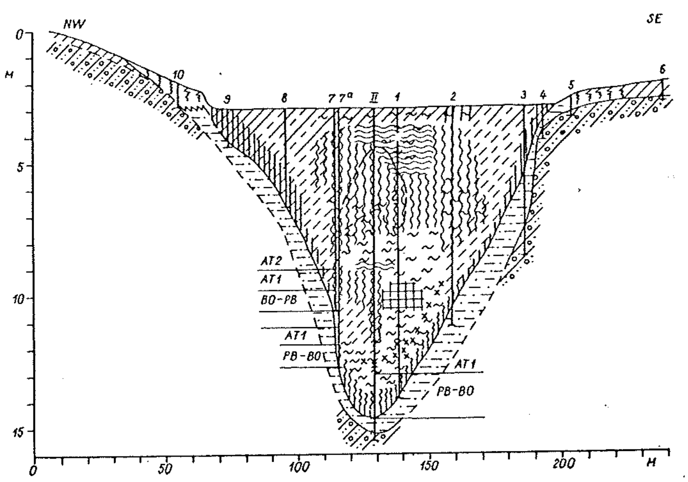

Рис. 2. Поперечный профиль отложений золля Синиаллика. Усл. обозн. см. на рис. 3.

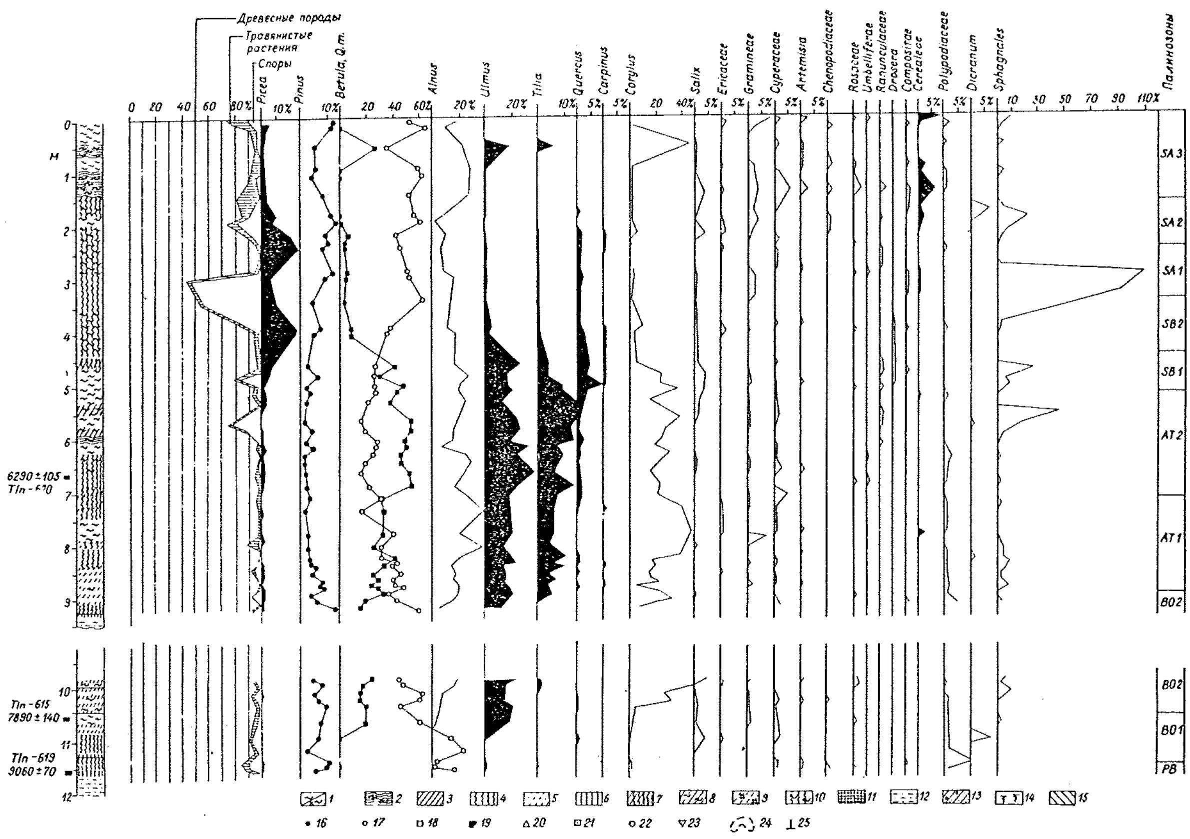

Рис. 3. Спорово-пыльцевая диаграмма отложений нижней части скв. II (9,8—12,0 м) и скв. I (0—9,5 м) в 10 м от скв. II. **Виды торфа:** *1* — сфагновый и хвоще-сфагновый, *2* — пушицево-сфагновый, *3* — осоковый, *4* — тростниковый, *5* — гипновый, *6* — древесный, *7* — осоково-тростниковый, *8* — осоково-сфагновый, *9* — сапропелевый гипновый, *10* — сфагново-тростниковый; *11* — сапропель, *12* — алевритовые отложения, *13* — морена, *14* — делювий, *15* — покровная супесь; **Пыльца:** *16* — сосны, *17* — березы, *18* — ольхи, 19 — широколиственных, *20* — ели, *21* — древесных пород, 22 — травянистых растений; *23* — споры; *24* — вода и торф, насыщенный водой; *25* — буровые скважины. (Палинологический анализ проведен Т. Кофф, определение торфа — М. Илометсом. Палинозоны по К. Каяк и др., (1976)).

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18/IV 1985

Reet PIRRUS, A.-M. RÕUK, Tiiu KOFF

LAIUSE SINIALLIKA SÖLLI EHITUS JA ARENG

Väikeste sulglohkude kompleksne uurimine võimaldab täpsustada morfogeneetiliste protsesside kulgu mandrijää taandumise ajal ning selgitada hilisjääaegse ja varaholotseense paleogeograafia erijooni. Käsitletav Siniallika söll on üks paljudest Saadjärve voorestikus leiduvatest. Ta asub voorestiku põhjaosas Laiuse voore lael (joon. 1). Nüüdisajaks on lehtritaoline nõgu suures osas täitunud madalsooturbaga, mille maksimaalne paksus on 11,6 m (joon. 2). Setete palünoloogilise uurimise ning ^{14}C analüüsi andmeil (joon. 3, 4) arvatakse, et vaadeldava glatsiokarstilise nõo moodustumine toimus põhiliselt holotseeni esimesel poolel. Oluliseks võib pidada ka väikeste sulglohkude setete palünoloogiliste andmete informatiivsust lokaalse paleotaimkatte kohta.

Reet PIRRUS, A.-M. RÕUK, Tiiu KOFF

GEOLOGY AND DEVELOPMENT OF A KETTLE HOLE ON THE LAIUSE DRUMLIN (EASTERN ESTONIA)

The investigated kettle hole of Siniallika is situated on top of the Laiuse drumlin (absolute height 144 m, relative height 60 m) in the northern part of the Saadjärv drumlin field (Fig. 1). The 130 m long and 90 m wide kettle hole has by now to a great extent been filled by fen peat of extremely variable content with a maximum thickness of 11.6 m (Fig. 2). A palynological study of the deposits as well as the ^{14}C analysis show (Fig. 3, 4) that layers of the same age within the limits of the kettle hole are situated at considerably different heights (Fig. 2). This circumstance together with the changes in peat content refer to the local sinking of land surface as a result of the melting of buried ice clod. The formation of the kettle hole mostly took place from the preboreal climatic period to the first half of the Atlantic period.

The complex study of small kettle holes enables us to detail morphogenetic processes during the retreat of continental ice and to make out different features in Late Glacial and Early Holocene paleogeography. Of significance is the information on local paleoflora obtained through the palynological study of the sediments of the kettle hole.

TARTU

Tartu is the second largest town in Estonia, the population is 100 577 (as of autumn 1999). Tartu is situated in Southern Estonia, 186 km from the capital Tallinn, on the picturesque banks of the river Emajõgi. Tartu's area is 38.8 sq km. Parks, gardens and the green belt cover 4.4 sq km of its territory.

The town is considered to be the oldest in Estonia, having been first mentioned in historical chronicles as early as 1030. The centre of Tartu gets its distinctive character from buildings rarely more than two centuries old. And if Tartu has now and then been called Athens on the Emajõgi, the neo classicist style of the buildings is one of the reasons for this. Tartu is one of the oldest university town in Europe. Without Tartu our universities would not be what they are. And, without our universities Tartu would not be what it is.

On 30 June 1632, the King Gustav II Adolf of Sweden signed the Foundation Decree of Academia Dorpatensis which enables us to mark the beginning of our university's distinguished history. The first students immatriculated between 20-21 April 1632. The opening ceremony of *Academia Dorpatensis (Academia Gustaviana)* took place on 15 October in the same year. The academy in Tartu functioned with Philosophy, Law, Theology and Medical Faculties enjoying the privileges of the University of Uppsala.

Tartu University developed dynamically in the years 1820-1890. The years 1855-1880 considered to be an inward-looking era of academic life but the graduates, on the contrary, consider it to be a second renaissance. Moritz Hermann Jacobi, the inventor of galvanoplastics, Karl Ernst von Baer, the founder of the theory of evolution and contemporary embryology, Wilhelm Ostwald, the founder of physical chemistry and the discoverer of salt effects, Alexander Schmidt, the founder of the fermentation theory of blood coagulation and blood transfusion principles, and many others studied and taught at Tartu University.

In the main building of Tartu University (built in 1805-1809 in the classical style) there is the oldest museum in Tartu University – the Art Museum. In the History Museum of Tartu University housed in the ancient Dome Church on Toome Hill visitors can familiarise themselves with the history of the university. The Botanical Gardens of the University, founded in 1803-1806, add charm to the ruins of the Tartu town wall and the bastion on the right bank of the River Emajõgi.

INSTITUTE OF BOTANY AND ECOLOGY (TARTU UNIVERSITY)

Compiled by Tsipe Aavik

Historical remarks

The history of Tartu University began in 1632, when the King Gustav II Adolf of Sweden signed the decree to establish *Academia Dorpatensis*. The faculties then included those of Philosophy, Law, Theology and Medicine. There was no separate chair in biology, few courses on natural history were taught in the Faculty of Medicine.

After the whirls of historical events Tartu University was reopened in 1802 as *Kaiserliche Universität zu Dorpat* or *Imperatorskij Derptskij Universitet*. The 19th century was considered to be a second renaissance – e.g. Moritz Hermann Jacobi, the inventor of galvanoplastics, Karl Ernst von Baer, the founder of the theory of evolution and contemporary embryology, Wilhelm Ostwald, the founder of physical chemistry and the discoverer of salt effects, Alexander Schmidt, the founder of the fermentation theory of blood coagulation and blood transfusion principles, and many others studied and taught at Tartu University.

After reopening in 1802 botany was taught at the Medical and Philosophical Faculties of Tartu University. The former had a Department of Botany and Materia Medica, the latter a Department of Natural History and Botany. Gottfried Albrecht Germann was the first professor of botany in Tartu University. The subsequent professors of botany were: C. Fr. Ledebour (1811-1836), corresponding member of the St. Petersburg Academy of Sciences, author of the first Russian flora - "Flora Rossica"; Alexander Georg v. Bunge (1836 -1867), honorary member of the St. Petersburg Academy of Sciences, the founder of the geographical-morphological method in plant taxonomy; Heinrich Moritz Willkomm (1868-1874), corresponding member of St. Petersburg Academy of Sciences, investigator of the Pyrenean Peninsula, dendrologist and phenologist; Edmund Russow (1874-1895), corresponding member of St. Petersburg Academy of Sciences, cytologist, plant anatomist and sphagnologist; Nikolai Kuznetsov (1895-1914), corresponding member of St. Petersburg Academy of Sciences, investigator of the flora of the Caucasus.

After the establishment of Tartu University as the national Estonian language university in 1919, mycologist F. Bucholtz (1919-1923) became the professor of botany and head of the Botanical Institute. He was followed by H. Kaho (1923-1924), academician of the Estonian Academy of Sciences and plant physiologist; E. Spohr (1924-1930), researcher of water plants; T. Lippmaa (1930-1943), academician of the Estonian Academy of Sciences, biochemist, plant ecologist and geobotanist.

During the period of soviet occupation the heads of the Department of Plant Taxonomy and Geobotany at Tartu State University were: systematic August Vaga (1944-1956), academician of the Estonian Academy of Sciences, chief editor of the 11-volume "Flora of the Estonian S.S.R."; Hans Trass (1956-1962), academician of the Estonian Academy of Sciences, lichenologist and ecologist; Viktor Masing (1962-1964), academician of the Estonian Academy of Sciences, biogeographer and telmatologist, and again Hans Trass (1964-1991). In 1986 the department was renamed the Department of Botany and Ecology. During the reorganization in 1992 four chairs were established: botany, plant ecology, mycology and applied ecology. The head of the institute from 1992-2004 was Martin Zobel, geobotanist and plant ecologist. The head of the Chair of Applied Ecology, Olevi Kull, is leading the institute at present.

Contemporary research directions

There are four main research directions in the Chair of Plant Ecology. First, experimental and theoretical research of species coexistence mechanisms and explanation of the spatio-temporal variation in species diversity as such and more specifically in some certain community types (calcareous and floodplain grasslands, hillock forests etc.). Second, study of the ecological significance of morphological plasticity of herbaceous plants. Third, ecology and dynamics of rare vascular plant species populations in Estonia (*Pulsatilla patens, Gladiolus imbricatus* etc.). Fourth, the role of multitrophic interactions (i.e. mycorrhizal, mucophyllae, rhizobium, nematodes etc.) in vascular plant community life and experimental study of the role of arbuscular mycorrhizal in plant competition and seedling establishment.

First of the main directions of research of the Chair of Botany is the study of the evolutionary-historical aspects of grassland species richness, and management of grassland communities. Special interest is paid to vascular plant community characteristics as determinants of bryophyte diversity. The second important field is the study of systematics, morphological and genetic variability of several plant taxa (*Alchemilla, Rubus, Dianthus* etc.) using traditional and molecular methods. Third, the life cycles of planktonic microorganisms in the vertical flux of organic matter in the ocean are being investigated.

Main research direction of the Chair of Applied Ecology is related to the adaptation of the photosynthesis apparatus to the light gradient in plant canopies and to the ontogenetical development of structural and functional characteristics of leaf water regime and photosynthesis. Second direction deals with woody plants under environmental stress, more specifically with the impact of air pollution on the functioning of photosynthesis apparatus. The third broad theme is the role of different environmental factors in the formation of forest carbon balance. Fourth research direction is the study of plant water relations and hydraulic architecture of trees.

One of the main research fields of the Chair of Mycology is the molecular phylogeny, ultrastructure and taxonomy of fungi, mainly *Basidiomycetes* and *Lachnum* and related genera (*Hyaloscyphaceae, Helotiales, Ascomycetes*). The second field of study are mycorrhizal associations between *Thelephorales* (*Basidiomycetes*) and vascular plants. Third, the composition and conservation of Estonian lichen flora, phylogeny and systematics of cetrarioid lichens, problems of taxonomy of lichenized ascomycota are being investigated.

Botanical Garden

The Botanical Garden of the University of Tartu was founded in 1803. In 1806 the garden was relocated to its' present site, on the ruins of the ancient city wall and fortifications near the river and ponds. The first director of the Garden was Prof. Gottfried Albrecht Germann and the first chief gardener in duty was Johann Anton Weinmann. Weinmann made the first master plan of the Garden and it serves till nowadays. In 1811 Prof. Carl Friedrich Ledebour was nominated the director. Under his active leadership, the collections of the Garden were enriched by many new species, collected from Siberia and other unexplored regions of the Russian Empire, and firstly described by Ledebour. Most of them reached Western Europe via our Garden. Many other famous botanists and his successors as Ernest Rudolf Trautvetter, Karl Johan Maximowicz, Alexander Georg von Bunge, Edmund August Friedrich

Russow, Nikolai Kuznetsov, Theodor Lippmaa have contributed to the development of this marvellous Garden. The Garden contains several monuments gratefully reviving the memory of our forerunners' contribution.

Field collections of the Botanical Garden include those of monocots, dicots, the Perennials' Garden, the Rock Garden, the Rose Garden and the Arboretum. Besides, the Palm House and the Succulents' House enable to make acquaintance with plants from warmer regions of the world. The Subtropical House is currently under construction.

The main function of the Botanical Garden is introducing the basis of botany, gardening and general natural history to students, pupils and other visitors. Much attention is paid to the methods of garden design to attract people to go in for gardening. New decorative plant species are presented. One of the latest activities is compiling the seed bank of rare, protected, scientifically and culturally valuable plant species. The Botanical Garden is also responsible for the administration and complementation of the database of Estonian plant names. Apart from the scientific and aesthetic value of the plant collections the Garden serves also a nice place to arrange cultural events. Several open-air concerts have taken place there. The stationary exhibition of stone sculptures made by famous Estonian sculptor Anton Starkopf diversifies the aesthetic impression of the Botanical Garden.

More information:
http://www.ut.ee/ - web-site of Tartu University
http://www.botany.ut.ee/ - web-site of the Institute of Botany and Ecology, Tartu University
http://www.ut.ee/botaed/ - web-site of the Botanical Garden of Tartu University

THE OTEPÄÄ UPLAND

The Otepää Upland with its highly varied hillocky relief rises more than 100 metres above the surrounding plains. It was formed of sediments accumulated mostly during the last Ice Age, and in some localities the thickness of the sediments reaches 200 metres. The thick Quaternary cover here also contains some sediments of earlier glaciations.

The boundary of the Otepää Upland can be quite easily distinguished in those places where it is marked by primeval valleys, or where these valleys run parallel to the upland, such as the Rõngu Valley and the Elva Valley in the west, the Voika-Tatra Primeval Valley in the north and the Reola Valley and also partly the Ahja Primeval Valley in the east. The upland has no clear boundary in the southeast, where it joins the Karula Upland. The area of the upland is about 1200 km^2, and it reaches about 40 kilometres across from both south to north and from west to east.

The Otepää Upland can generally be divided into two higher parts divided by a partly buried ancient valley, running from north-northeast to south-southwest, which rises only 120–130 meters above sea level. In the north this glacial valley joins the valley of the Elva River, and in the south it is continued by the valley of the Väike Emajõgi River. The valley is marked by three bigger lakes — Lake Pangodi, Lake Nõuni and Lake Pühajärv. The part of the upland lying in the west of the ancient valley is smaller, more distinct and rises higher above sea level. The highest hills of the upland are located here, among them Kuutsemägi (217 m), Kõrgemägi (214), Tsiatrahvimägi (213 m) and Harimägi (212 m).

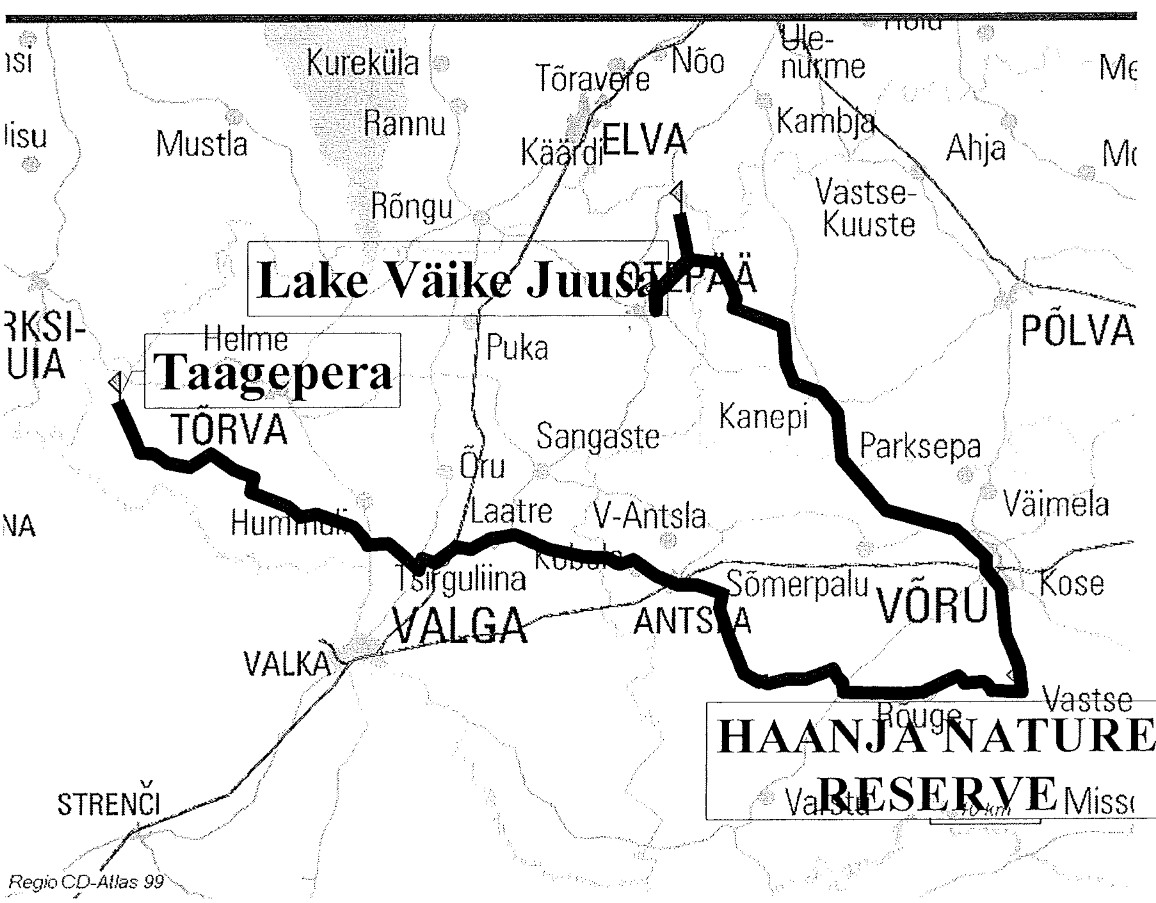
The larger, but shallower, eastern part of the upland is divided by numerous primeval valleys into smaller hillocky areas and rolling plains. Its higher and more uneven part extends between Lake Pühajärv and the border of the counties of Valgamaa and Põlvamaa. Located here are dome-shaped Väike Munamägi (207.5 m) and Tedremägi; in the east lie Tõikamägi (210 m) and Laanemägi (211 m). The neighbourhood of Pangodi Village and Kambja Köstrimäed also have more dissected relief.

The south-eastern part of the upland, mostly rising less than 150 meters above sea level, is remarkable for the abundance of relatively deep (up to 40 metres) valleys, such as the Kooraste, Jõksi–Piigandi, Erastvere–Ahja and Urvaste primeval valleys.

Wednesday
25 August

Lake Juusa - Haanja Nature Reserve – Vällamägi – Suur-Munamägi

Wednesday, 25.08.04



THE OTEPÄÄ NATURE PARK

An area of 232 km2 in the central part of the Otepää Upland, in Valgamaa County, has been zoned for protection. In 1979 Otepää Landscape Protection Area was created by joining together the areas of the previous smaller protected areas of Lake Pühajärv, Väike-Munamägi and Tedremägi and by adding some new areas. In 1996 the area was renamed the Otepää Nature Park. The main functions of the nature park are to protect local variegated landscapes and to further traditionally developed ways of managing these areas to prevent harm to the landscapes. For this purpose the reserve area has been zoned into areas of strict protection and areas of moderate economic activities. The nature park has favourable conditions for developing tourism and recreation, and for winter sports. Nature study paths have been marked to give better access to specific features of relief.

LAKE VÄIKE-JUUSA

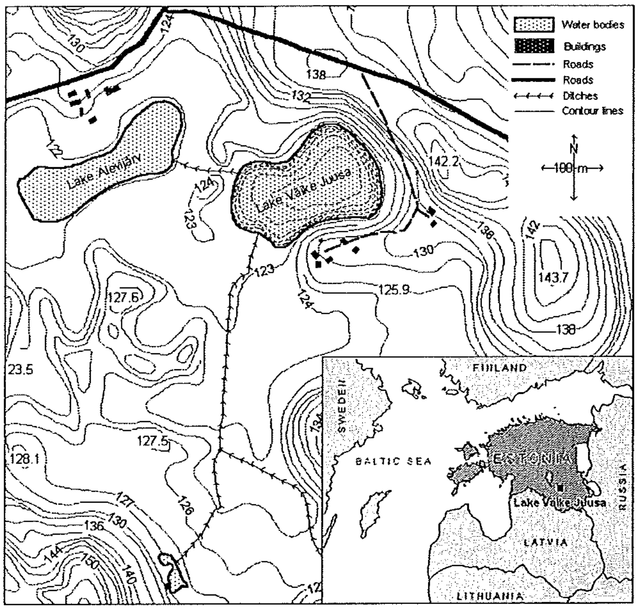
Lake Väike-Juusa (hereafter L. Juusa) is situated in the southern part of Estonia (58° 03′N and 26° 32′E) on the Otepää Heights. The relief of accumulative Otepää Heights is topographically varied and complex. Small depressions between hillocks were formed after the withdrawal of the Scandinavian Ice sheet during the Otepää stage about 12 200 BP and many basins like L. Juusa have a glaciokarst origin. The hillocks bordering the lake have steep slopes. To the west of lake there is a paludified area and a depression that connected now separated lakes Juusa and Alevijärv. There is one inlet from the east and also a man-made ditch connecting lakes Juusa and Alevijärv. The climate is continental with cold winters and warm summers. The mean summer temperature is 16.5 °C and the mean winter temperature is 6 °C. Mean annual precipitation is ca 650 mm.

L. Juusa is a small lake of 3 ha with maximum length of 250 m and width of 160 m. The mean depth is 3.7 m and a maximum depth is 6.0 m in the eastern part of the lake. It is a eutrophic dimictic lake with strong stratification during spring-summer. During the summer the thermocline deepens from about 2.5 m in June to 3–3.5 m in July–August. The concentration of oxygen has a very distinct seasonal cycle. Its vertical gradient during the period of convective mixing is a consequence of higher consumption in the deeper layers compared to the supply by vertical transport. The oxygen content in the near-bottom layers approaches zeroing during the year. The decrease of temperature in September induces the gradual onset of autumnal circulation and the water column becomes unstratified by the end of October. The values of pH were ca 7.7 in the surface of the water column and 6.6 at 5 m during 2002–2003.

The bottom sediments of L. Juusa are up to 12 m thick in the deepest point of the lake. The surface layers of sediments are brownish gyttja with high water content and organic matter. Estimated from the ^{210}Pb data the uppermost 10 cm of sediment in the deepest point accumulated during the last 10 years.

The drainage area of L. Juusa is 55 ha comprising semi-open cultural landscape. The vegetation around the lake consists of pine forest on the hill to the west of the lake and mixed spruce forest on the eastern side. There was intensive agriculture around the lake until the 1990s, presently there is only some small-scale farming to the south.

The shoreline vegetation is formed from 50 different taxa indicating the variability of habitats around the lake. The emergent macrophytes most frequently found are *Phragmites australis* and some *Carex* species. *Typha latifolia, Schoenoplectus lacustris, Acorus calamus* are rather abundant and are distributed evenly along the shoreline. The floating-leaved plant *Nuphar lutea* is found occasionally. Submerged plants such as *Potamogeton praelongus* and *Elodea canadensis* are more widely distributed in the western part of the lake. Based on the macrophyte classification and typology of Estonian lakes this type of vegetation is common for eutrophic lakes.



The location of Lake Väike-Juusa

The spatial variability of diatoms, subfossil macrophytes and OC/N values in surface sediments of Lake Väike-Juusa (southern Estonia)

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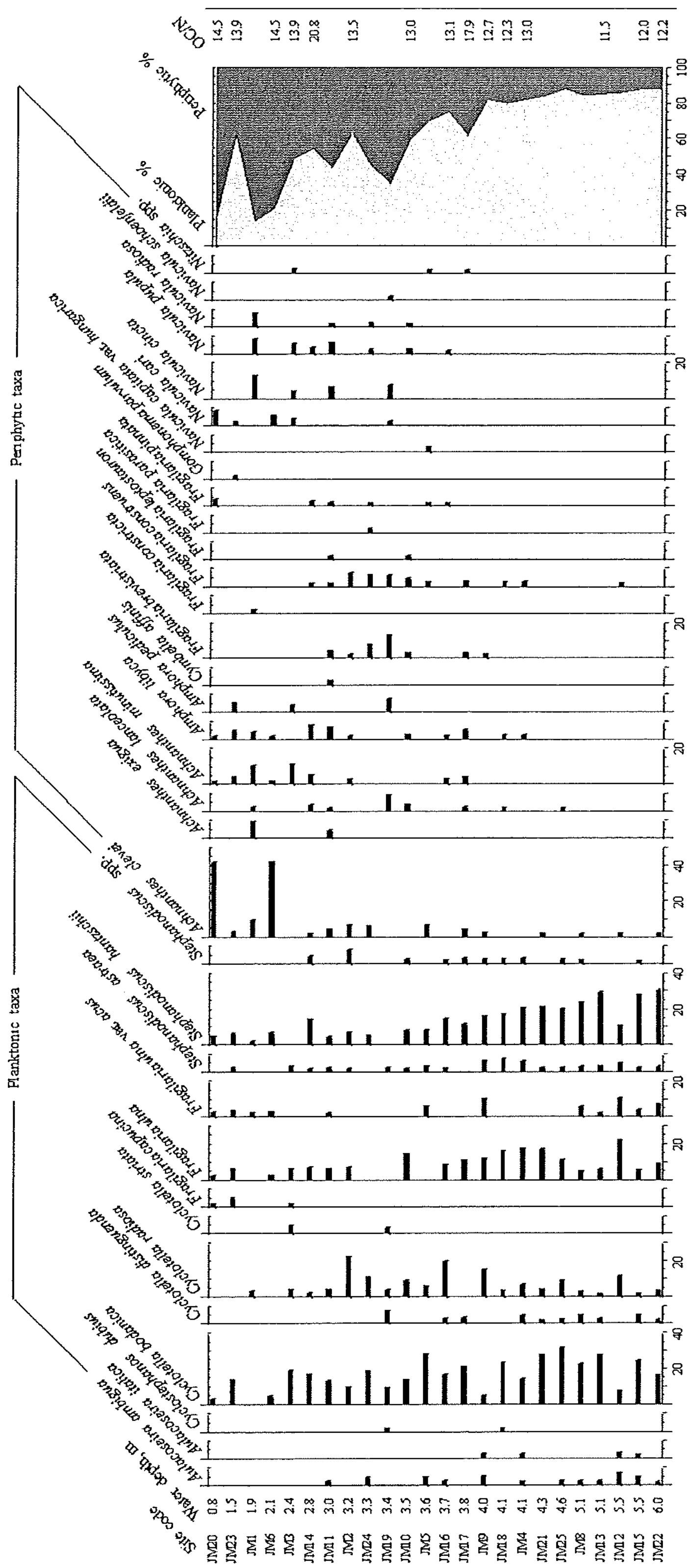
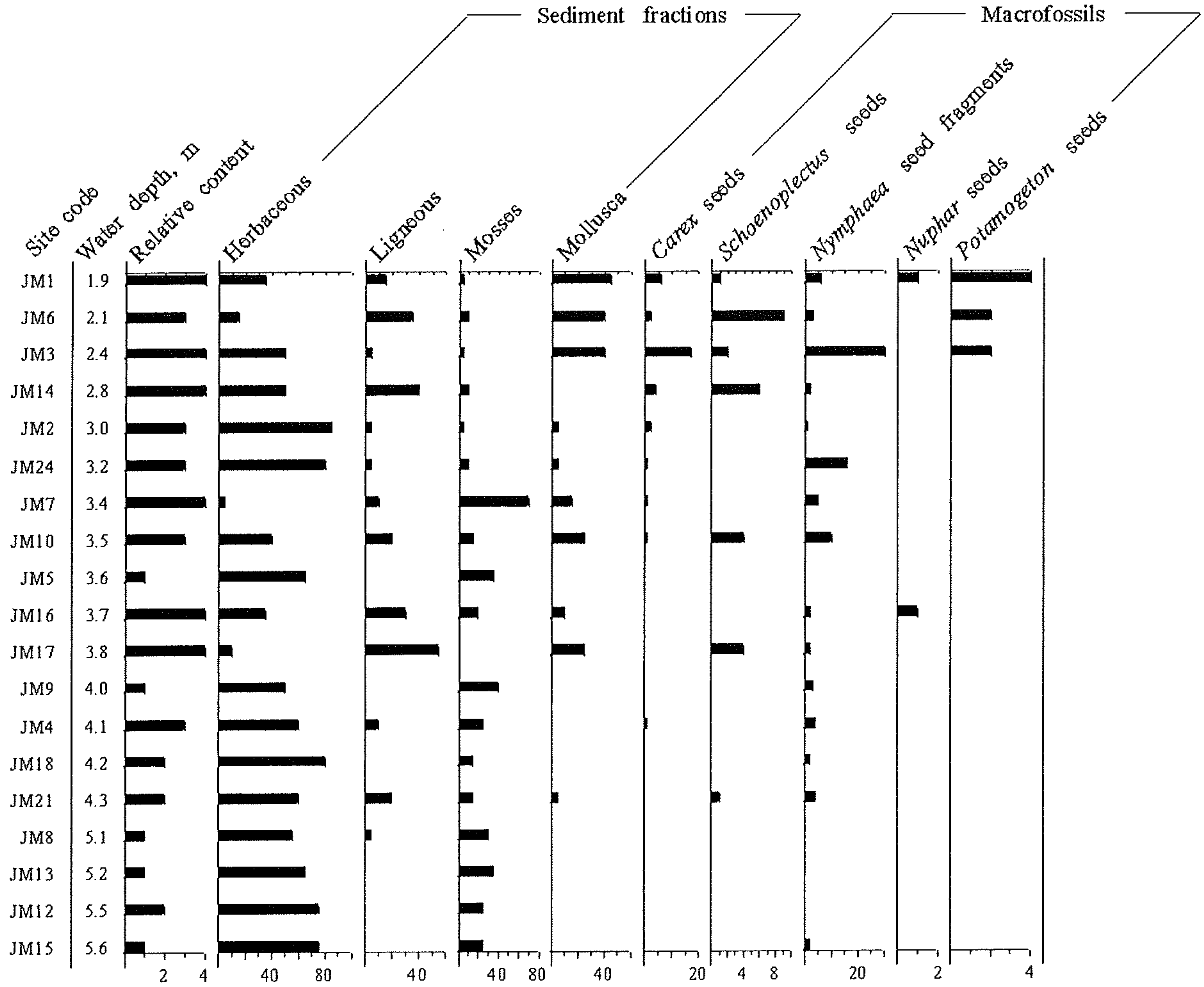
Abstract. The diatom assemblages, organic carbon nitrogen (OC/N) ratio and macrophyte remains in surface sediment samples from the small dimictic Lake Väike-Juusa in southern Estonia were analysed. The results obtained show that changes in the composition of diatoms, macrophyte remains and OC/N values are in logical dependence from the water depth in the studied site. So the species richness and number of periphytic diatoms is higher in samples collected in the littoral area, from depths up to 3.5 m. The abundance of macrophyte remains is higher in the littoral. OC/N ratio reflecting the share of planktonic matter in the bulk organic matter has a tendency to increase from the littoral towards the profundal zone. The similar tendencies of the data obtained by three different methods enable to apply this approach for lake-level change research in the past.

Key words: diatoms, macrofossils, OC/N, small lake, surface sediment



The relative abundance distribution of diatoms in surface samples (from Lake Väike Juusa) expressed according to the water depth. OC/N values of bulk organic matter are shown on the right.



The distribution of macrofossils in surface samples (from Lake Väike Juusa) expressed according to the water depth. The relative content of the amorphous organic matter is given from 1 to 4, the fractions of the sediments in percentages and macrofossils as number of seeds per 100 cm^3 of the sediment.

MACROFOSSILS IN THE SEDIMENTS OF L. JUUSA (SOUTHERN ESTONIA)

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Introduction

Aquatic macrophytes are macroscopic forms of aquatic vegetation, which include macroalgae (e.g. the alga *Cladophora*, the stoneworts such as *Chara*), the few species of mosses and ferns adapted to the aquatic habitat as well as true angiosperms (Wetzel, 1983). Macrophytes are part of the lake ecosystem and their composition and distribution depend on external factors such as climatic conditions and internal processes like lake metabolism. Macrophyte ecologists have not yet reached a consensus on the relative importance of different environmental factors in determining the biomass of submerged macrophytes in lakes. Heegaard et al. (2001) demonstrated that the most influential variables are related to local scale chemical and nutrient composition and suggest a strong local influence on species composition of different lakes, leading to the interpretation that the occurrence of a species in a lake is predominantly controlled by the catchment.

During 1961–1985 Aime Mäemets (1991) described and mapped the vegetation in more than 90 small lakes in Estonia. She concluded that most of the macrophytes, particularly submerged vegetation, are in good accordance with the hydrobiological types of lakes, reflecting at the same time changes of the macrophyte vegetation accompanying eutrophication and dystrophication of soft-water lakes (Mäemets, 1991).

In brief, we can say that the distribution of macrophytes in lakes is connected with the content of nutrients in the lake, its nutrition type, water-level changes and climatic conditions as well as the interrelationships of these factors. Modern monitoring data allow us to follow the changes that have occurred in recent decades. However, here it is important to take into consideration that all species need not develop in different years, which complicates estimation of the status of a water body if data are incomplete (Mäemets, 1991). In addition, it is necessary to bear in mind that macrophytes are characterised by slow response to environmental changes, and thus the factors that have caused the change may originate from much earlier periods (Ott & Kõiv, 1999).

Therefore, information on long-term changes is needed. The fact that part of macrophytes are preserved as macrofossils in sediments is known already since the beginning of the 20th century (Chaney, 1924). A macrofossil includes any part of a plant preserved after its death in the sediments that is large enough to be seen by the naked eye. Plant macrofossils are diaspores (seeds, fruits, spores) and vegetative parts, such as leaves (including cuticles, leave, spines, etc.), buds, budscales, flowers, bulbils, rhizomes, roots, tissue fragments, bark, and wood (Birks, 2001). The majority of plant macrofossils identified are seeds and fruits.

Attempts have been made to use the distribution of fossil macrophytes in sediments in palaeoecological studies on lakes. As one of the most important factors influencing the macrophyte distribution is water column depth the fluctuations of lake level changes cause changes in aquatic vegetation assemblages and may shift their distribution zones (Hannon & Gaillard, 1997). The most recent study of Tarras-Wahlberg et al. (2002) shows that water-level fluctuations have a significant effect upon sediment characteristics and changes in aquatic vegetation assemblages. However, it is necessary to consider various other influences that may significantly affect the distribution of vegetation as well as the preservation of macrofossils in the sedimentation process and sediment diagenesis.

For interpreting the macrofossil data, information on the habitats of plant communities (such as water depth and chemistry, lake bottom slope and lithology of surface sediments) is needed. Also it is necessary to investigate how well the plant remains can be preserved in the lake sediments. The only information about the mechanism of macrofossil deposition in lake sediments comes from surface sample studies (Birks, 1973). It is important to know which plants will be represented by macrofossils in lake sediments and whether it is informative to use this information for estimations of the abundance of the plant in the past vegetation, the lake trophy or changes in the water level.

Although the macrofossil technique is fully established (Watts, 1978; Birks, 1980, 2000) and its contribution to palaeolimnology is validated (Ammann, 1989; Lotter, 1999; Birks & Wright, 2000) the method has not been systematically used in Estonia. Also additional studies on the modern plant–macrofossil–water-depth relationships in different types of lakes would be invaluable for strengthening and refining the interpretation of fossil records. Therefore studies on the distribution of macrofossils in various types of lakes are needed in Estonia. With this knowledge, coupled with an increase in knowledge on habitats and ecological requirements of aquatic and marsh plants, much useful information could be gained about past limnic and terrestrial conditions by studying plant macrofossils in lake sediments.

THE HAANJA UPLAND

The Haanja Upland is the most 'mountainous' area of Estonia. It is situated in southeastern Estonia and extends to Latvia in the south and to Russia in the east. The area in Latvia is also known as the Aluksne Upland or the East Vidzeme Upland. The most elevated parts lie in the central and northern part of the upland, in the territory of Estonia, but a height of 250 meters and more above sea level can be found over quite a large area. Here the highest elevation of the Baltic countries — **Suur-Munamägi (318 m)** located, and nearby stands another hill reaching higher than 300 m — Vällamägi (304 m). The latter is also the natural relief element of Estonia of the largest relative height, its top rising 88 m from its foot by Lake Perajärv. The hills of Kerekunnu (296 m) and Tsälbamägi (293 m) are the third and the fourth highest hills in Estonia.

The Haanja Upland has a notably distinctive border in the northwest and north, where it rises sharply from the outwash plain of the Hargla Depression and its eastern elongation, the Võru Vale, towards the south and southeast. The line of its base is less pronounced in the west, where the southern edge of the Hargla Depression separates the Haanja and Karula Uplands from each other. A relatively lower territory, Paganamaa, dissected by deep depressions, lies in this area. The length of the upland from north to south at the Latvian border is 30 kilometres, and from west to east at the Russian border it covers about 40 kilometres.

The overview of the Haanja Upland differs greatly in different parts. The long-distance view towards the "peaks" of the upland opens from the northern slope of the Võru Vale. The highest hillocks and the largest ridges which are, in their turn, surrounded by a belt of lower hillocks, lie in the central part of the upland, around the village of Haanja that has lent its name to the entire area. The latter part is cut by deep valleys — Kütiorg and the Piusa primeval valley, beginning in the centre of the upland and descending towards the north. The Hinsa hillocks, situated between these two valleys, are of geological interest, as they lie on the bedrock elevation covered with the Upper Devonian carbonate rocks.

The Vana–Saaluse–Vastseliina vale is located south of the Hinsa hillocks. The vale has formed above a buried valley (the bottom of this valley lies up to 60 m below sea level). The Vale is filled by an outwash plain, and at the middle reaches of the Piusa River, the relief is quite even. To the south of the valley, between the villages of Vastseliina and Ruusmäe, and in the southeast up to Luhamaa Village the relief is much varied with depressions and hillocks of medium height. In the western and southeastern part of the upland there is a distinctive hillocky area cut by valleys, extending from Trumbipalu up to Krabi Village in Paganamaa.

The Haanja Upland is an area of extremely diverse nature; besides uneven relief there are numerous water bodies, plenty of forests and a heterogeneus network of small villages. The Haanja region has the largest number of lakes in Estonia — there are about 175 small or large lakes. The majority of small lake depressions have formed as a result of the melting of blocks of dead ice. A number of these lakes have grown over and become mires. The lakes in the valleys have dissected coastlines, such as Lake Kavadi at Uue-Saaluse; the lakes in the valleys cutting into the slopes of the upland are oblong and deep (the lakes of the valleys of Kütiorg, Piiriorg and the Rõuge Valley). Beautiful Lakes Vaskna and Tuuljärv are located near Suur-Munamägi. Lake Tuuljärv is, at 257 meters above sea level, the highest lake in Estonia. The biggest lakes of the eastern part of the upland are Lake Kirikumäe, which gives rise to the Pedetsi River flowing towards Latvia, Lake Misso and Lake Hino. On the slopes of the buried valleys, springs release karst water rich in lime.

Dissected relief, varied Quaternary cover and diverse water conditions have favoured the development of mosaic vegetation. Human activities have played an important role in this process. Every patch of land suitable for cultivation was turned into fields a long time ago. Many former fields have overgrown with forest again. Besides productive spruce and mixed forests there are secondary birch and aspen forests and plenty of shrublands.

About half of the territory of the Haanja Upland is covered with forests. All kinds of forest types represented in Estonia, except alvar forests, can be found here. In older stands spruce dominate, usually reaching considerable height here. A good example is the virginal forest covering Vällamägi, where the trees are about 40 metres tall. Broad-leafed forests, once characteristic of the region, have mostly been cut and turned into fields. Broad-leafed forests have been preserved only in river valleys or on very steep slopes of hillocks, where the tree layer is rich and varied (lime, elm, oak, maple, ash). Depressions between hillocks are mostly wet and paludified, dominated by swampy forests of alder and birch stands, or by mires of different stages of development, mostly nutrient-rich fens; transitional bogs and raised bogs are rarer. The peat layer has been determined to be the thickest in Estonia — 17 meters — in a bog by the foot of Vällamägi.

The relative influence of local, extra-local, and regional factors on organic sedimentation in the Vällamäe kettle hole, Estonia

JAAN-MATI PUNNING, TIIU KOFF, MATI ILOMETS AND JAAN JÕGI

BOREAS

Punning, J.-M., Koff, T., Ilomets, M. & Jõgi, J. 1995 (March): The relative influence of local, extra-local, and regional factors on organic sedimentation in the Vällamäe kettle hole, Estonia. *Boreas*, Vol. 24, pp. 65–80. Oslo. ISSN 0300-9483.

This paper examines the data obtained during a complex study of a 17 m deep peat sequence in a small glaciokarstic kettle hole mire in SE Estonia. The pollen and macrofossil analysis and the ^{14}C data were used for the spatio-temporal reconstruction of the development of the mire, including its vegetation and microclimatic conditions during the Holocene. The comparative analysis of the data gained allows us to estimate the relative influence of various local, extra-local, and regional natural processes on the dynamics of the ecosystems.

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The reconstruction of paleogeographic conditions and the developmental pattern of an ecosystem is mostly based on the study of organic sediment sequences. The interpretation of the analytical data is often complicated due to the complex nature of the course-consequence relationships. During the last decades, a number of studies have been devoted to the problems concerning the influence of environmental processes controlled by a variety of different time and space scales on the development of vegetation, ecosystem and landscape structure. A theoretical concept of the spatio-temporal division of geographical systems has been developed (Delcourt & Delcourt 1988; Birks 1993), but practical solving of these problems is often hindered by a lack of suitable study objects. An objective estimation of the response of the ecosystems to the climate change is operative over a broad spectrum of temporal and spatial scales. Much basic research has been devoted to these problems, and the main principles of the paleoecological reconstructions have been worked out (Berglund 1986; Delcourt & Delcourt 1991).

In our earlier studies, we pointed out that the state and dynamics of ecosystems in mosaic-glacial landscapes may differ considerably due to the variety of the physical environments at different scales (Ilomets 1984; Koff 1991, 1992; Punning 1991). Because ecosystems are affected by a range of external factors, a detailed study of sequences from a series of mires and lakes of different sizes may produce a more complete picture of the development of a single ecosystem.

The aim of the present study was to estimate the share of the local and extra-local climatic and hydrologic factors in the formation of vegetation and pollen record composition of a small (1.62 ha) kettle hole with a maximum thickness of organic deposits up to 17 m. Plant macro-and microfossil analyses were used, microclimatic variability at different stages of mire development was calculated, and principal paleogeographic features were reconstructed.

Site description

The small mire studied is situated in Haanja Upland in south-eastern Estonia (Fig. 1). The major relief features in this area were formed in the beginning of Gotiglacial time, about 13 000 years ago, when the retreating Scandinavian glacier shaped a continuous belt of marginal landscape forms from western Lithuania to Lake Onega in Karelia (Serebryanny & Raukas 1966). Ice-marginal formations are represented by hills with a thick cover of till as well as by glaciofluvial and lacustrine sediments. Quaternary deposits are poor in carbonate (Raukas 1978). Dead-ice plains played an important role in the formation of the present landscape. The dead-ice blocks survived over a long period of time because they were buried under a thick soil cover. After the melting of the ice blocks, kettle holes were formed.

It is most likely that the lake and mire deposits studied by us were formed in a glaciokarstic kettle hole which obtained its final shape during the Preboreal period (see Mangerud *et al.* 1974), not later than 9000 BP (all dates are given in ^{14}C years).

The vegetation in this region is characterized by a mosaic of pine stands belonging to the *Pinus sylvestris – Vaccinium vitis-idaea – Pleurozium schreberi* association and spruce stands belonging to the *Picea abies – Oxalis acetosella – Rhytidiadelphus triquetrus* association (Laasimer 1965). Patchiness is the most characteristic feature of the vegetation, with forest stands, meadows and mires representing only small areas within the arable land. Sod-podzols are the prevailing soil type.

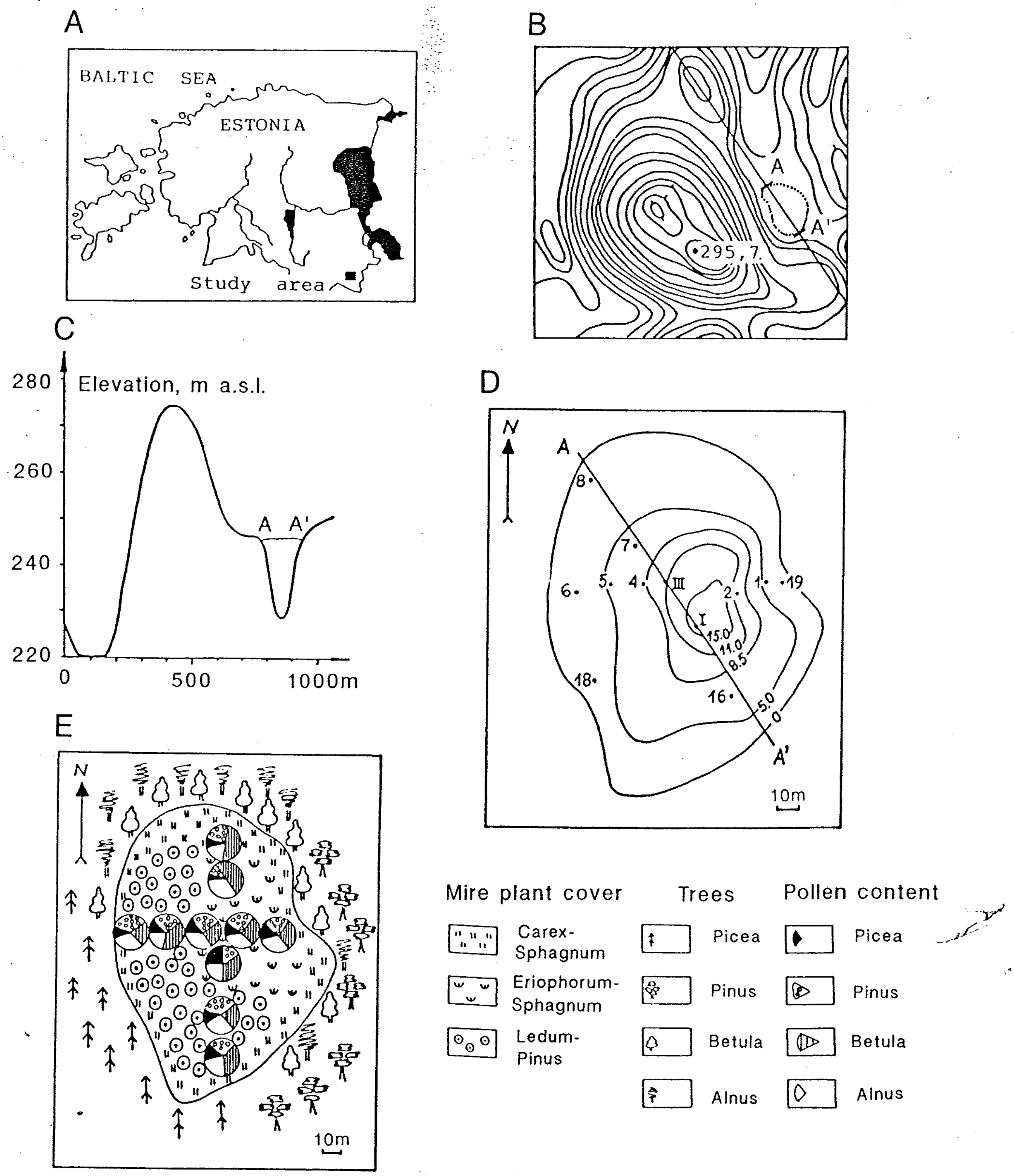
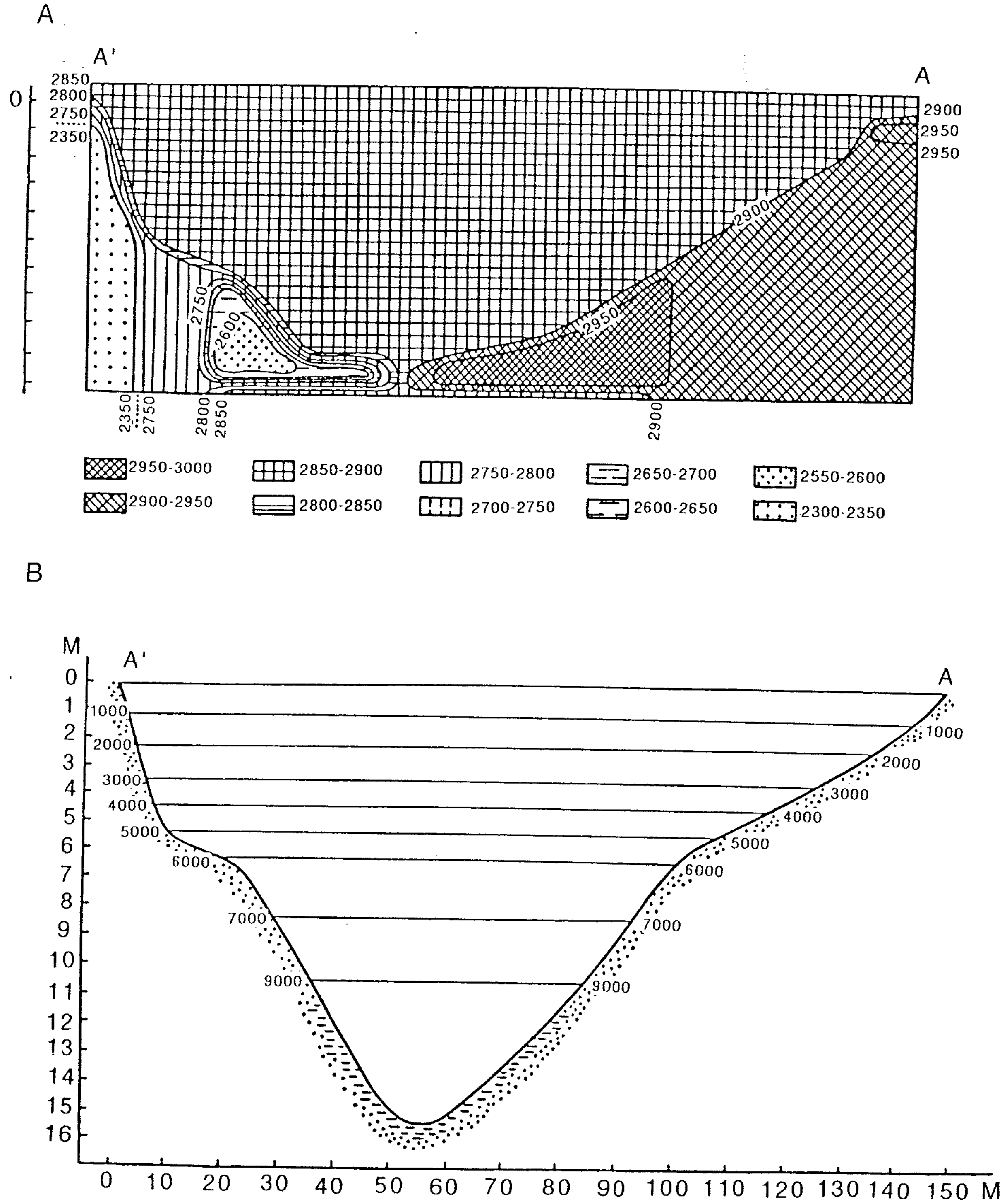


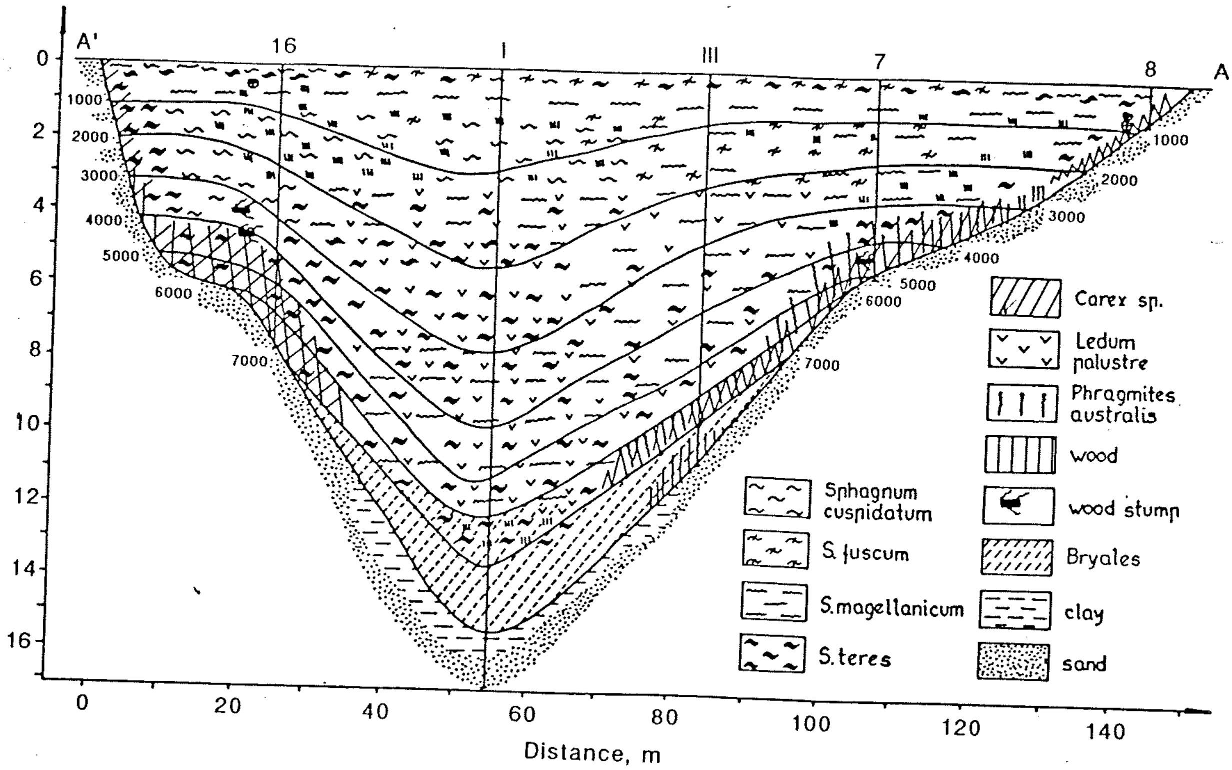
Fig. 1. □ A. Location of the study area. □ B. Topographical map of the investigated area. Contour lines with 5 m interval. □ C. Profile showing location of kettle hole (A–A'). □ D. Thickness of the organic deposits in m (contour lines) and location of the sites used for the reconstruction of paleoenvironment in the Vällamäe mire. □ E. Current vegetation of the mire and its vicinity, and the pollen content in surface samples.



'ig. 5. The spatio-temporal dynamics of the falling radiance on the slopes of the kettle hole in MJ/m^2 during the vegetation period (A) nd calculated paleosurfaces of the kettle hole mire (B).

eres) with *Phragmites* residues began to accumulate. ,ater *Phragmites* disappeared and is absent from the lant record up to the present day. In core V-I, the *'phagnum* peat with dwarf shrubs (*Ledum palustre* nd Vaccinium uliginosum) and herbs (*Carex inflata*, *C. vesicaria* and *Scheuchzeria palustris*) lie above the finely stratified peat and gyttja.

Further development of the kettle hole has proceeded to the present with insignificant changes in the composition of the plant cover. Throughout this time,



7. Cross-section of A–A' profile denoted in Fig. 1. with age isolines in years.

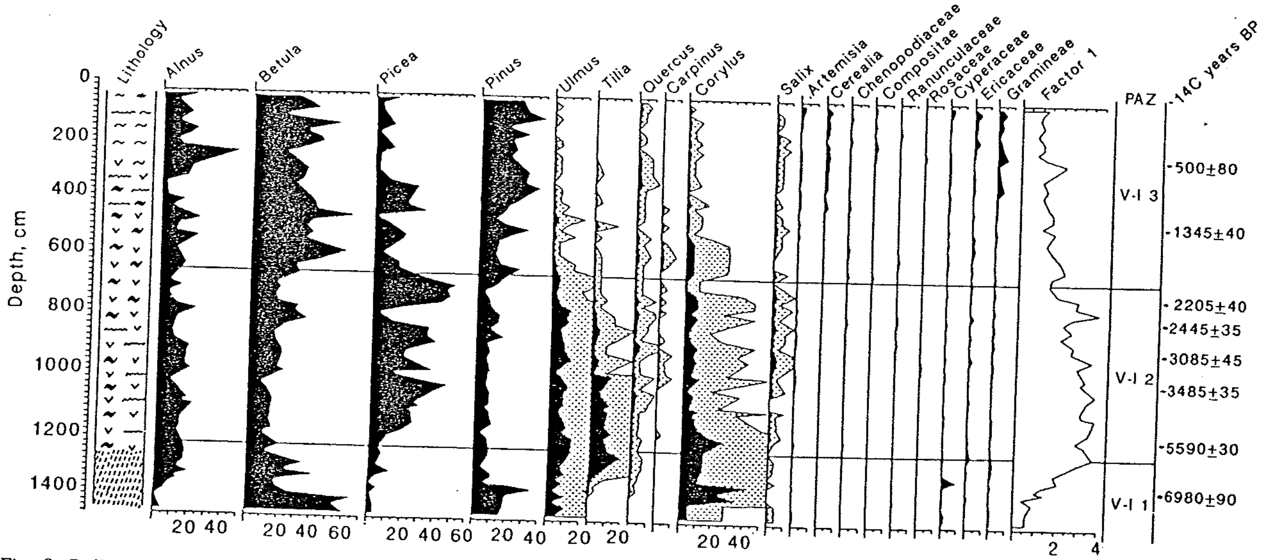


Fig. 8. Pollen diagram of the sediment core V-I.

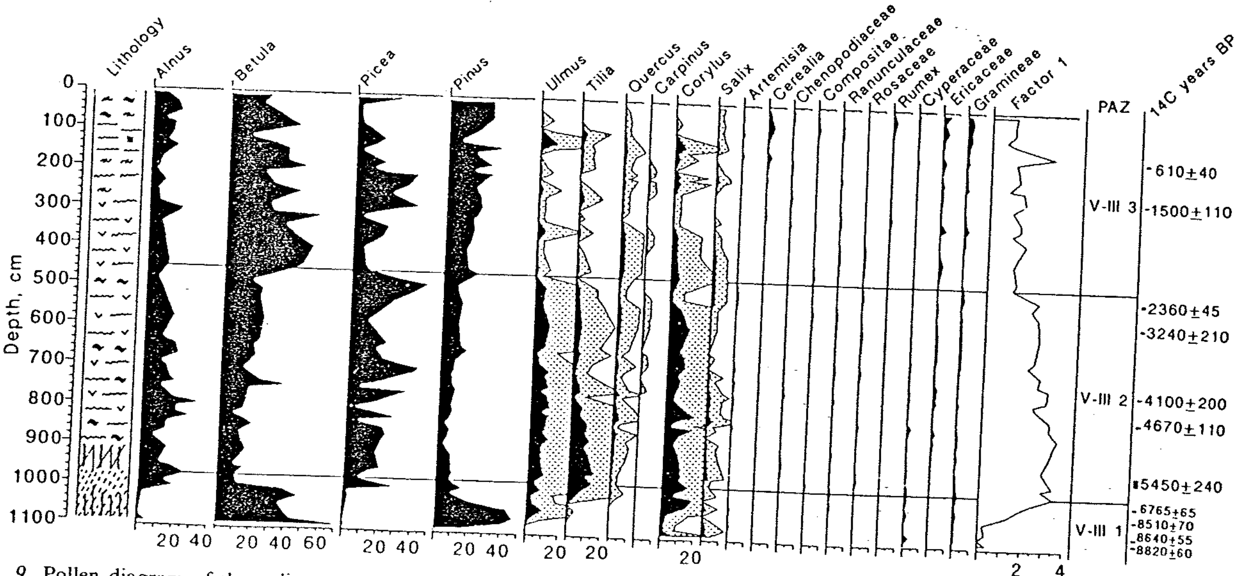


Fig. 9. Pollen diagram of the sediment core V-III.

Thursday
26 August

Nigula Nature Reserve

Thursday, 26.08.04

THE NIGULA NATURE RESERVE

The Nigula nature reserve is the first nature reserve created to protect mires in Estonia. The Nigula raised bog is a treeless raised bog of the western Estonian type; it has a relatively steep slope and flat central plateau. The slope can be best seen on the western edge of the mire system, where the surface of the bog rises up to 3 metres over a distance of a few tens of meters.

The pride of the Nigula mire system is five mineral islands in the raised bog, covered with old forest, which can be seen from far away over the raised bog, although the surface of these islands lies 1–1.5 meters lower than that of the bog itself. The higher parts of the islands are covered with broad-leafed forest rich in different plant species — a relic from the warm and wet Atlantic climate period that reigned here 5000–6000 years ago. The most prominent fauna group in the raised bogs are birds; changes in their numbers have been monitored here for decades. About 60 different bird species have been counted breeding on Salupeaksi, the mineral island with an area of 40 ha. The population density on the island is ten times larger than in the bog — more than 500 pairs of birds per square kilometre. There are numerous systems of bog hollows, which are the least accessible areas in the Nigula raised bog. The most difficult to cross are the areas of mud hollows, or quagmires — the peat mud, emitting swamp gases, does not offer any purchase for the traveller's feet.

Since 1965 cranberries have been cultivated at Nigula and research has been carried out. A Nigula collection — the gene pool of different forms of Estonian cranberries, has been formed. The Nigula rehabilitation centre for wild animals, created in 1996, is well known. The rehabilitation centre works on treating illnesses of wild animals, and helps them to rehabilitate in the wilderness after having been treated. A nature study path has been laid at the nature reserve, including a 6.8-kilometer-long boarded walk.

The main objective of the Nigula Nature Reserve (founded in 1957) is to preserve the peat-bog ecosystem as the major part of the reserve Nigula bog. The Nigula peat-bog occupies a total surface area of 2,342 hectares. According to Katz, it belongs to the coastal province of convex bogs of Estonia and Latvia, which form part of the complex of bogs in the Baltic region. According to Truu et al. the bog belongs to the region of large peat-bogs of South-West Estonia.

The Nigula bog is chiefly an open bog with an occasional low dwarf pine here and there. Sparse groves of pines, 5 to 10 m in height, grow only in places where the ground-water is comparatively rich in oxygen. These lie chiefly at the edges and on the marginal slopes of the bog as well as on the banks of large bog pools. The central plateau of the bog is well developed. Hence the marginal slope is well noticeable, particularly in the western part of the bog. The mesotrophic peatlands surrounding the bog are negligible or lacking altogether. 55% of the total area of the bog belongs to the complex of oligotrophic waterlogged bogs, 33% to the complex of bogs with hollows and 15% to the complex of healthy pine peat-moors. The system of pools here are rather extensive. There are over 370 large pools with mean depth of 2-3 m. The bog is halved by a chain of disconnected islets of firm land on mineral soil. It is about 100 to 200 m in width, trending N/S and covered with primeval deciduous forest. Part of the islets of firm land are covered with layers of peat. A relict lake with dark waters and a surface area of 17.6 ha lies in the eastern part of the bog. In several places there flow streams of water which here and there disappear beneath the peat. 144 species of birds inhabit the reserve. *Pluvialis apricata* with 65-70 pairs, *Tringa glareola* with 25-30 pairs, *Grus grus* with 3-4 pairs, *Numenius phaeopus, N. arquata, Lanius excubitor* are typical breeders to the bog habitat.

The Nigula bog has been little affected by human activities, although in some places filled in drains and a few open pits can be seen. Almost everywhere there is a boundary ditch running along the margin of the bog. The bog is surrounded partly by forests of the Nature Reserve, partly by stretch of intensively drained arable land which are separated from it by narrow strip of woodland.

АКАДЕМИЯ НАУК СССР

ИЗВЕСТИЯ
АКАДЕМИИ НАУК СССР
СЕРИЯ ГЕОГРАФИЧЕСКАЯ

(ОТДЕЛЬНЫЙ ОТТИСК)

УДК 551.58«0—2000»(474—16)

В. А. КЛИМАНОВ, Т. А. КОФФ, Я.-М. К. ПУННИНГ

КЛИМАТИЧЕСКИЕ УСЛОВИЯ ЗА ПОСЛЕДНИЕ 2000 ЛЕТ НА СЕВЕРО-ЗАПАДЕ ПРИБАЛТИКИ

Точность и детальность палеоклиматических реконструкций во времени в большой степени зависит от скорости осадконакопления, а также от частоты опробования отложений и достоверности выделения из них признаков климата прошлого. В частности, при палеоклиматических реконструкциях по палинологическим данным детальность в основном прямо пропорциональна мощности исследуемых отложений и частоте отбора проб на спорово-пыльцевой анализ.

В данной работе, используя информационно-статистический метод [3], в основе которого лежит статистическая связь современных спорово-пыльцевых спектров с климатическими условиями, мы попытались реконструировать количественные характеристики климата за последние 2000 лет. Для этого использовались палинологические данные из трех скважин одного из самых подробно изученных в нашей стране торфяник Нигула, который находится на водораздельном участке западного края Сакалаской возвышенности в Эстонии [5].

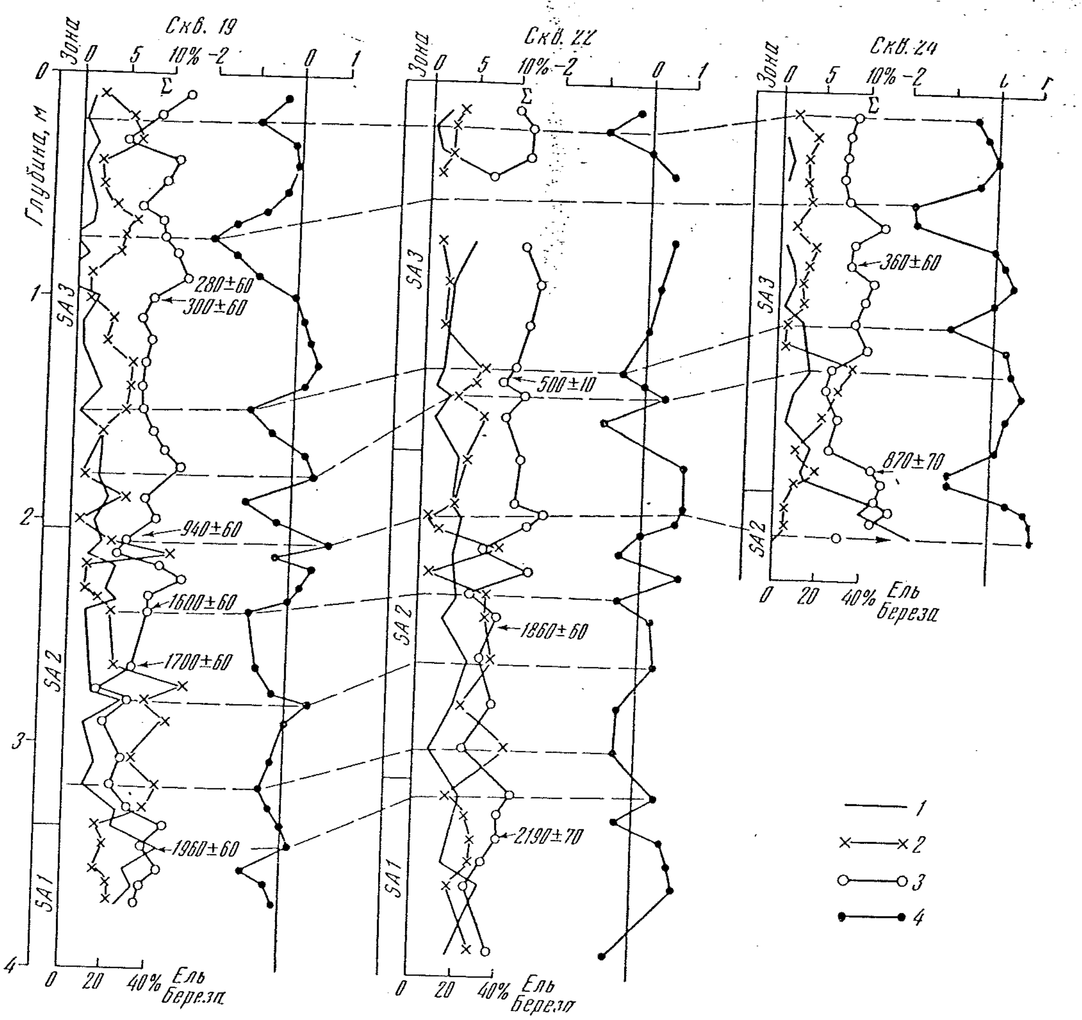


Рис. 1. Корреляция скважин торфяника Нигула по палинографическим данным и изменениям реконструированных средних температур июля: *1* — сумма пыльцы широколиственных пород, *2* — пыльца ели, *3* — пыльца березы, *4* — изменение температур июля

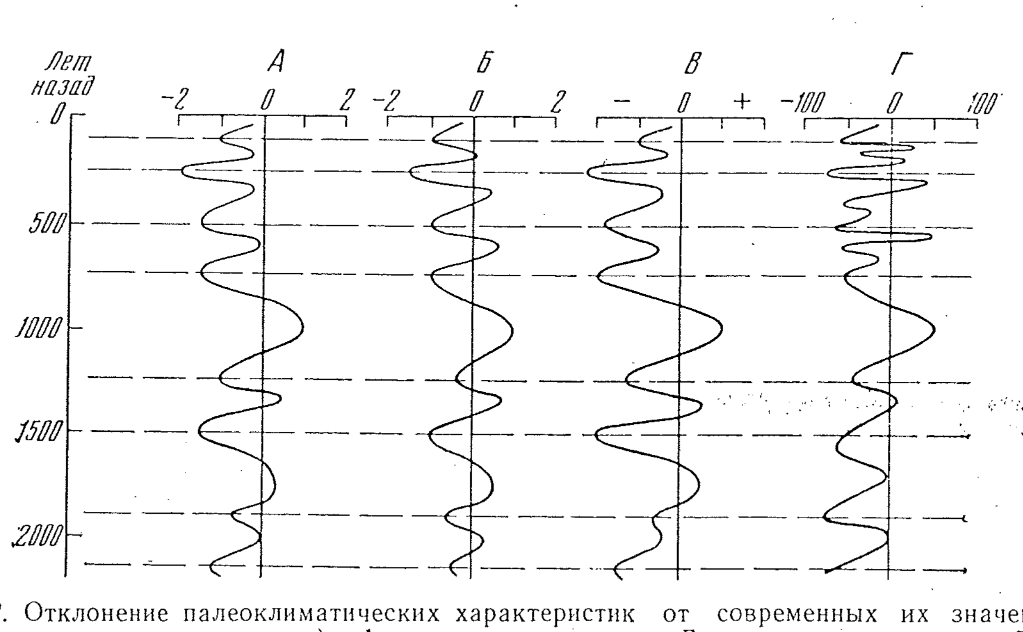


Рис. 2. Отклонение палеоклиматических характеристик от современных их значений (средние по трем скважинам). *А* — температуры года, *Б* — температуры июля; *В* — температуры января; *Г* — годовые осадки

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Der Einfluß der Entwicklung eines Hochmoores auf die Ausbildung der Pollenspektren am Beispiel des Nigula-Hochmoores (SW-Estland)

The influence of the bog development on the formation of the pollen spectrum on the example from Nigula Bog (SW-Estonia)

TIIU KOFF*)

ZUSAMMENFASSUNG

Aus drei nahe beieinander liegenden Profilen aus dem Hochmoor Nigula im südwestlichen Teil Estlands wurden Torfproben pollenanalytisch untersucht. Aus den so gewonnenen Ergebnissen und ihrer informations-statistischen und Clusteranalyse wurde zusammen mit den Ergebnissen der Radiokarbondatierung versucht, die Vegetation aus der Zeit vor 500 und 1000 Jahren zu rekonstruieren. Das Hauptziel dieser Untersuchung war, den Einfluß der Moorentwicklung und Mooraausdehnung auf das Pollenspektrum zu erforschen.

SUMMARY

Three peat cores situated closely to each other in the Nigula Bog SW-Estonia were palynologically analysed. Based on these data and their informational-statistical and clusteranalyses together with radiocarbon data the reconstructions of vegetation were made for different timespans: 500 and 1000 years ago. Main aim of this investigation was to see the influence of the expansion and the development of the peat bog on the formation of the pollenspectra.

+) Anschrift der Verfasserin: T.KOFF, Senior-Researcher, Institut für Ökologie, Kevade 2, EE001 Tallinn, Estonia

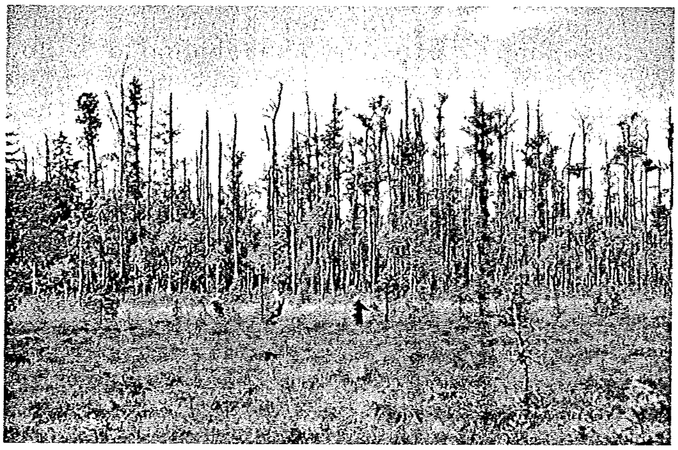


Abb. 1: Nigula-Hochmoor. Im mittleren Teil der Mineralbodeninsel Nr. 4 überwächst das Hochmoor den schilfreichen Erlenbruchwald und läßt die Bäume absterben (Foto R.STAMER)
Nigula Bog. In the middle of the mineralsoil-isle nr.4 the bog is overgrowing the Phragmites-Alnus glutinosa-forest. The trees are dying (Foto: R.STAMER)

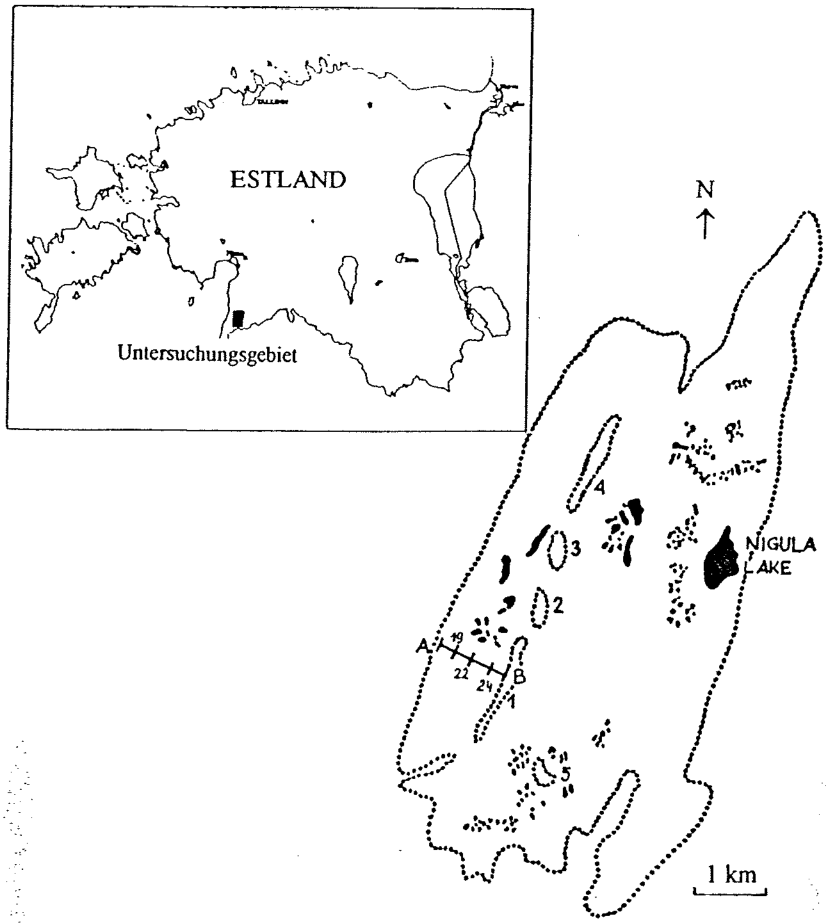


Abb. 2: Lageplan des Untersuchungsgebietes und Übersichtskarte vom Nigula-Moor mit dem Profil-Querschnitt A-B
Location map of the study area and scheme of the Nigula Bog and studied profile A-B

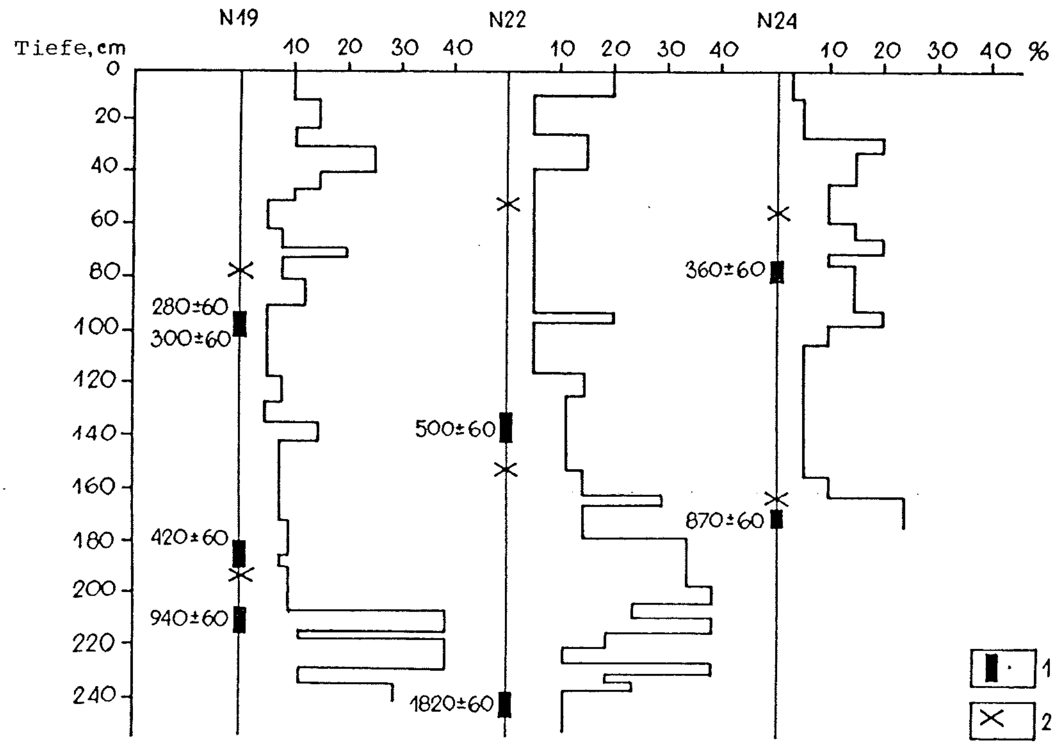


Abb. 5: Zersetzungsprozente der Torfe in den Profilen in N-19, N-22 und N-24. 1 - ^{14}C-Datierungen; 2 - paläoklimatisch synchrone Schichten im Torf nach KLIMANOV et al. (1986)
Degree of humification in cores N-19, N-22 and N-24. 1 - ^{14}C-datings; 2 - synchronous layers of palaeoclimatic reconstructions after KLIMANOV et al. (1986)

Die Extrema der Erwärmungen (Abb. 5) wurden als Vergleichsbasis zwischen den drei Profilen benutzt. Weiterhin konnte man in der Tiefenskala diesen Erwärmungen entsprechende Datierungen benutzen, und auch die anderen Maxima der Erwärmung und Minima der Abkühlung korrelieren.

Aufgrund der korrigierten Altersmaxima der ^{14}C-Datierung und der Daten aus der informativ-statistischen Analyse wurde das Alter einer jeden Pollenprobenschicht festgestellt (Abb. 6, 7, 8).

4. ERGEBNISSE

4.1 Verteilung der Pollen

Schon aus der informativ-statistischen Analyse (KLIMANOV et al. 1986) wurde klar, daß in allen Profilen gewisse synchrone Veränderungen als Folge von Klimaschwankungen zu beobachten sind. So zeigen sich beim vorläufigen Vergleich nach der Clusteranalyse zwei größere Cluster (Abb. 6, 7, 8), deren Altersgrenzen in den verschiedenen Profilen synchron sind; sie spiegeln deshalb die allgemeine, auf Regional- oder Makroniveau stattgefundene Veränderung wider. In allen drei Profilen zeigt sich eine derartige Veränderung vor 450-550 Jahren.

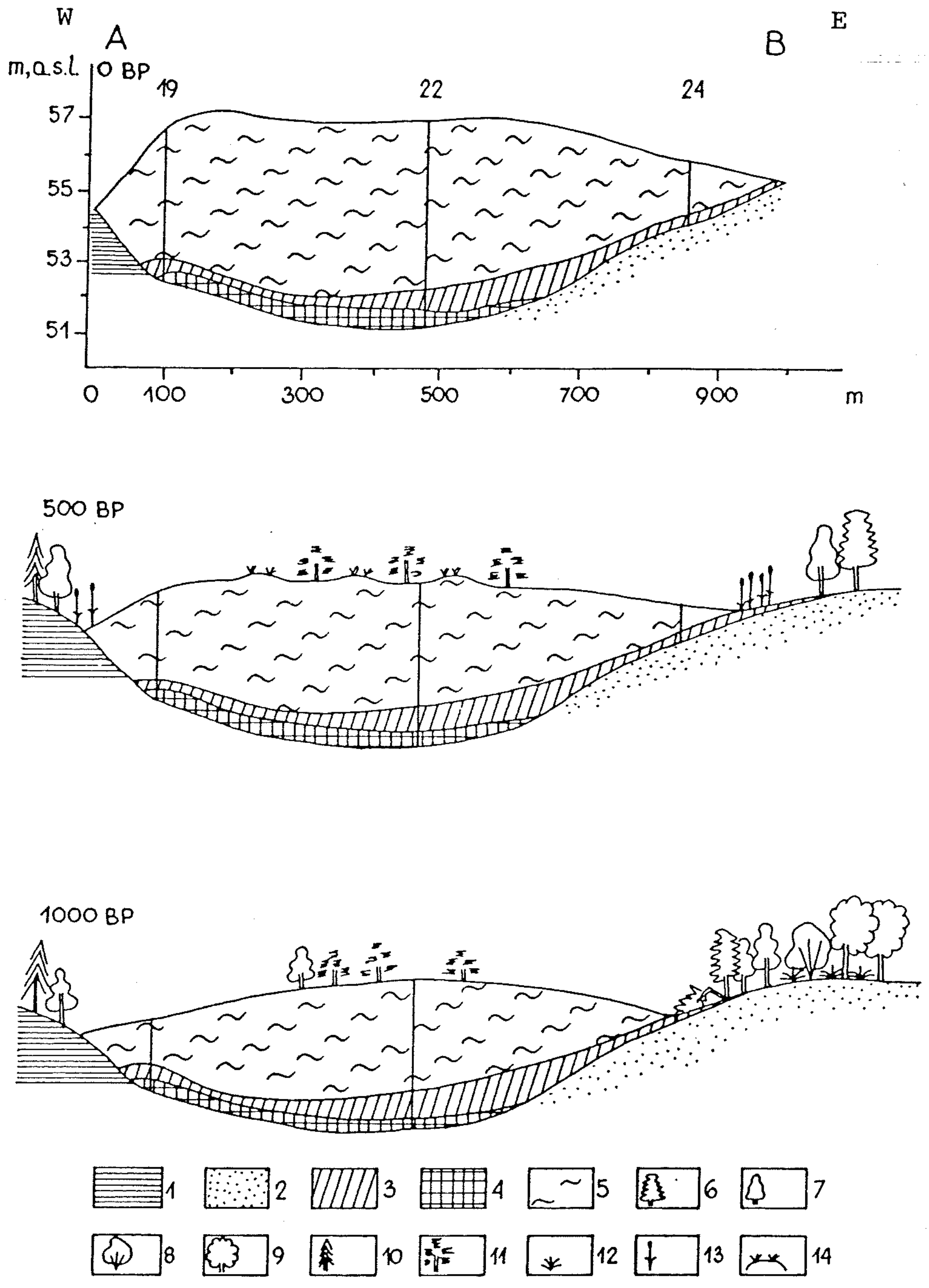


Abb. 9: Schema der Entwicklung des westlichen Teils des Nigula-Moores vor 1 000 und 500 Jahren und ein Querprofil des heutigen Moores. 1 - Ton; 2 - Sand; 3 - Niedermoortorf; 4 - Gyttja; 5 - *Sphagnum*-Torf; 6 - *Alnus*; *7 - Betula; 8 - Corylus; 9 - Tilia; 10 - Picea; 11 - Pinus; 12* - Polypodiaceae; 13 - *Typha; 14 - Calluna*

Scheme of the bog development in the western part of the Nigula Bog for timespans of 1 000, 500 years ago and the present. 1 - clay; 2 - sand; 3 - fen peat; 4 - gyttja; 5 - *Sphagnum*-peat; *6 - Alnus; 7 - Betula; 8 - Corylus; 9 - Tilia; 10 - Picea; 11 - Pinus;* 12 - Polypodiaceae; *13 - Typha; 14 - Calluna*

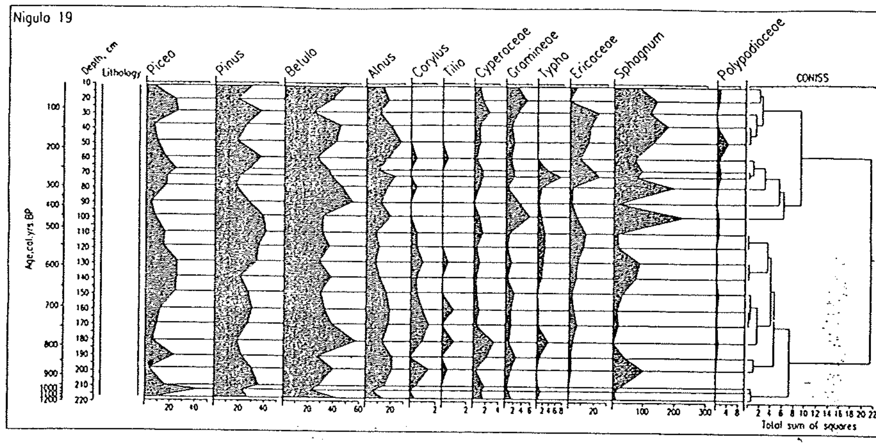


Abb. 6: Pollendiagramm des Profils N-19 aus dem Nigula-Moor
Pollendiagram of the peat core N-19 from the Nigula Bog

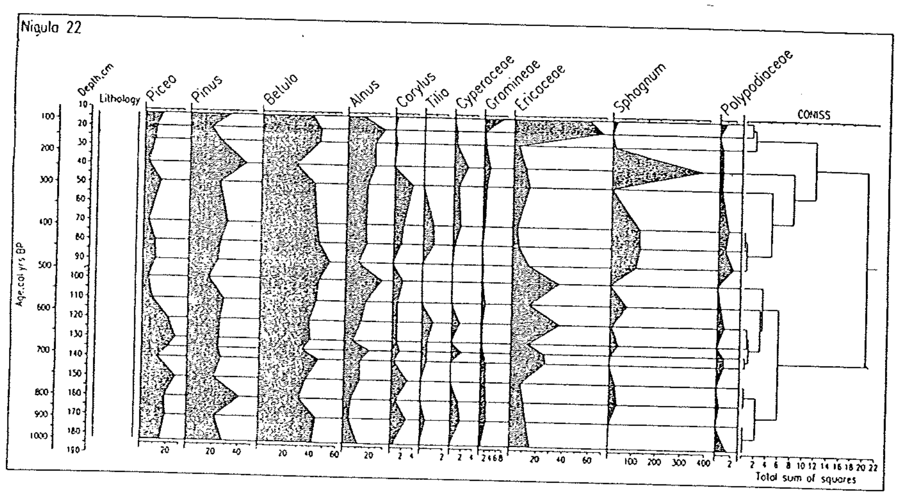


Abb. 7: Pollendiagramm des Profils N-22 aus dem Nigula-Moor
Pollendiagram of the peat core N-22 from the Nigula Bog

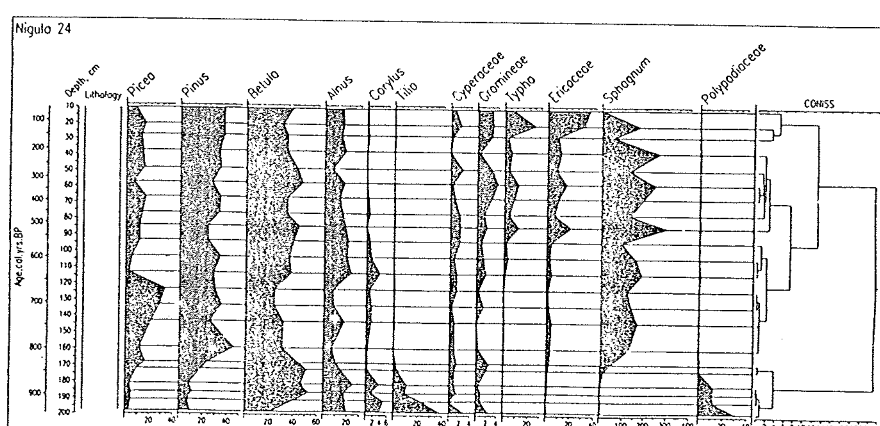
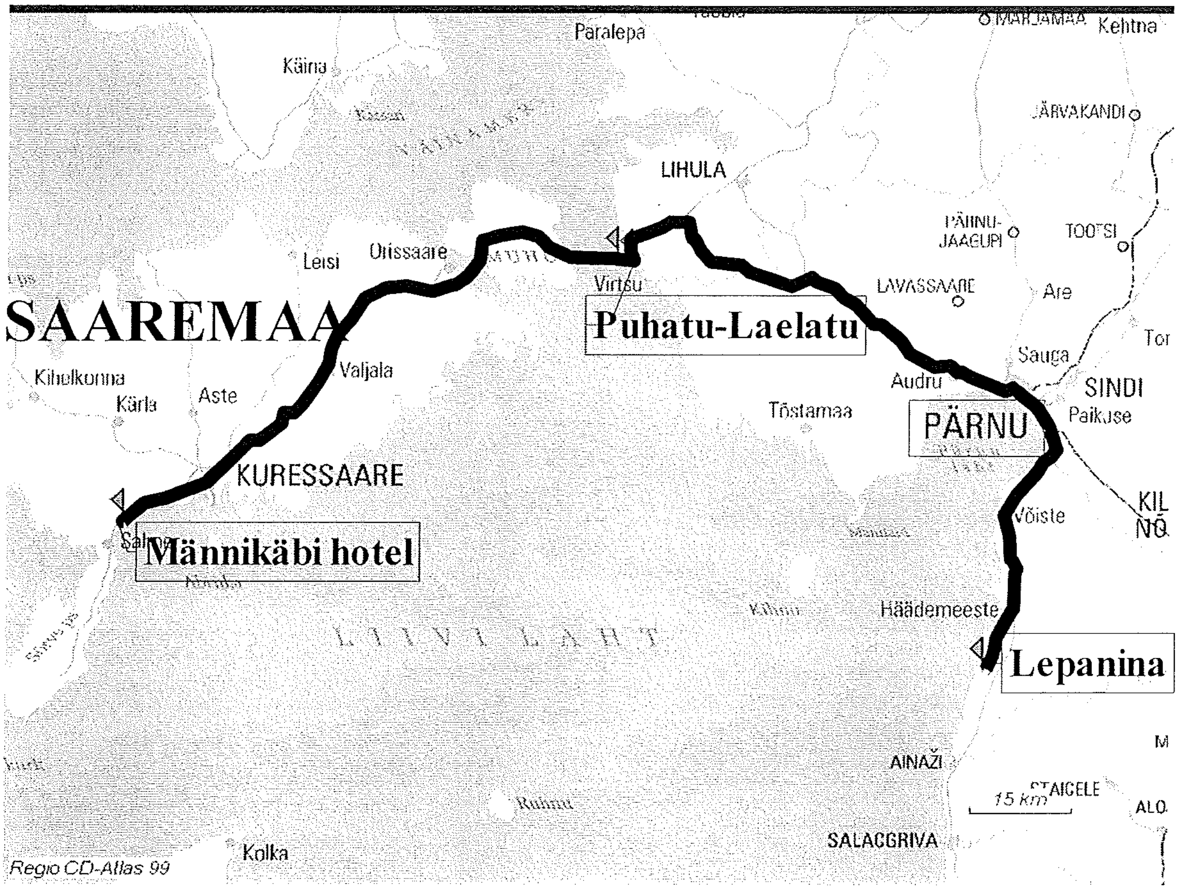


Abb. 8: Pollendiagramm des Profils N-24 aus dem Nigula-Moor
Pollendiagram of the peat core N-24 from the Nigula Bog

Friday
27 August

Rannametsa-Soometsa Nature Reserve – Puhtu-Laelatu Narure Reserve – Kõmsi stone cist barrow – Saaremaa

Friday, 27.08.04



RANNAMETSA – SOOMETSA NATURE RESERVE

This is the unique reserve in the Estonia. The present Nature Reserve with the territory of 9860 ha, was established in 2000. Merging together several smaller protected areas with different protection regime created it. The function of the reserve is to protect the present and former coastal landscapes from coastal areas up to postglacial sand dunes and peatlands. At the same time the reserve is also serving as the habitat for several rare or endangered animal and plant species. Lying at the Pärnu Lowland, this area consists all of the distinctive features of nature of the south-western Estonia: large and flat coastal formations, sand dunes, forests and mires. This region has deserved the designation as separate bio-geographical region - Littorale haedemeestense- due to its characteristic nature by the famous geobotanist Theodor Lippmaa.

On the territory of the Rannametsa – Soometsa Nature reserve, it is possible to follow the 8000 years long history of the development of the Baltic Sea and landrise. This is made possible by the chain formations of the Ancylus Lake and Littorina Sea sand dunes. The first of them is known as Võidu – Soometsa dunes and second as Rannametsa dunes consequently.

Between these two chains of dunes - ancient coastlines, lays the **Tolkuse bog**. This bog is formed from the coastal laguna of the Littorina period, by the paludification of the ancient bay. Behind the Soometsa dunes is situating the Maarjapeakse or Soometsa bog. This bog is formed by the paludification of the shallow and wet terrain. The Tolkuse bog is divided (split) by the hand dug channel Timmkanal, made by the local landlord in the middle of the 19.th century. In the river bank near the village Rannametsa is situating the representative cross-section of the geological past of the area from the Littorina sand until Devon sandstone.

From the west of the Rannametsa dunes lays the flat plain land, gradually raised from the Baltic Sea. This sandy and stony coastal zone consists large meadows and reed beds. The shoreline is very complex with many bays and capes. The sea on the area of the reserve is very shallow, with temporary sandbanks and mudflats, numerous stony riffs and islets.

There is no local administration of the Rannametsa – Soometsa Nature Reserve. The statutory administrative functions are carried out by Pärnu County Environmental Department of the Ministry of the Environment. The LIFE project

"Restoration and Management of the Häädemeeste Wetland Complex", implemented locally by the Estonian Ornithological Society, is to help to carry out several conservational tasks, ranging from development of the management plan, restoration and management of various habitats to development of the visitors infrastructure and rising of environmental awareness.

This work will be done in novel way, in partnership with statutory and local institutions and together with local stakeholders. The landscape of the reserve, specifically the dunes and bogs has been traditionally favoured site for recreation and outdoor activities. This is partly due to good road access to the reserve, especially by crossing of Via Baltica major highway. The state forest area of the reserve is a part of the Pärnu – Ikla recreation zone of the state forest management organization RMK. This body is responsible on the development and maintaining of the visitor's infrastructure on state forest and carrying out this task in co-operation with reserve administration and LIFE project. The area is very interesting as birdwatching destination and amount of relevant visitors is increasing constantly.

There is nature trail and other visitor's attractions in the Rannametsa dunes and Tolkuse bog and several birdwatching towers at coast. There is a published visitor's map and information leaflet for the reserve. In spite of the Nature Reserve and the new conservation values discovered, the certain restrictions to the visitor access have created, most of the places like dune forest, bogs and coastal areas have free access. This is because of the goal of the reserve to serve as site for exposing and demonstrating the natural values and rise environmental awareness.

RESTORATION AND MANAGEMENT OF THE HÄÄDEMEESTE WETLAND COMPLEX

This is an EU LIFE-Nature project (LIFE00NAT/EE/7082) at Rannametsa – Soometsa Nature Reserve. The project is carried out by the Estonian Ornithological Society as beneficiary and main implementing body. The goal of the project is preserving and restoring the nature conservation values of the reserve with the EU and national importance. For achieving this goal, the project will be implemented in close co-operation among beneficiary NGO, statutory- and local municipality institutions, with local land managers and other stakeholders. In the project is foreseen to carry out several habitat restoration activities as pilot ones in order to get experiences on the applicability of these methods countrywide.

Very important part of the project is development of the infrastructure and opportunities for the awareness rising and dissemination of the project results.

The EU funds the project in ¾ share and the other contributors and the partners are:

* Ministry of Environment, Pärnu County Environmental Department
* RMK – State Forestry Centre
* Häädemeeste Municipality

GENERAL INFORMATION OF THE PROJECT

* Beginning of the project 01.08.2001
* End of the project 31.05.2005
* Beneficiary:
* Eesti Ornitoloogiaühing (Estonian Ornithological Society) Partners:

  Häädemeeste municipality

  RMK - State forestry centre

  Pärnu County, Environmental Department of Ministry of Environment

  OÜ Aminolte Donor:

* * EU LIFE Nature programme Project Office :

  Häädemeeste, Pärnu mnt. 40, II floor

GOALS OF THE PROJECT:

* Secure the favourable conservation status of habitats and species with the EU and national importance
* To get experiences on management of the future Natura 2000 area with the complex range of habitats, threats and interests
* Achieve control over land use, recreation and tourism activities and lead them toward sustainability
* Test the model of reserve management as partnership of the statutory organizations, NGO, local managers and stakeholders
* Use the project as demonstrative example for various kind of pilot activities of habitat restoration and management
* Involvement of the local society to the conservation management and economic improvement
* Rise the public awareness and enhance the understanding of current nature conservation highlights

PROJECT ACTIVITIES Preparatory activities

* Management plan for the Nature reserve
* Hydrological assessment of the Tolkuse bog
* Land use agreements and contracts with the landowners

Single-time restoration activities

* Blocking the drainage ditches for water level control in Tolkuse bog
* Pilot bog restoration on former peat extraction field
* Restoration of open sand patches on dunes

* Restoration of former fishpond as wetland
* Restoration of water level management in coastal meadows
* Creating of livestock grazing infrastructure
* Restoration of shallow spawning ponds for Natterjack Toad
* Preparation of coastal meadows for grazing and mowing

Activities for the continuos habitat management

* Livestock purchase for coastal meadow management
* Grazing of livestock for coastal meadow management
* Managing the coastal meadow by mowing

Activities for the awareness-rising and demonstration of the project results

* Media work and informing public about the project
* Guided visits to the project sites
* Children's summer camp
* Meetings with local farmers, landowners and other stakeholders
* Seminars for conservation professionals on project results
* Pupils creative competition
* Creation of photographic database of project
* Travelling photo exhibition
* Project WEB-page
* Visitor map and information leaflet for Rannametsa-Soometsa Nature Reserve
* Leaflet for farmers/landowners
* Development of facilities for sustainable tourism regulation
* Creation of camp sites and hiking cabins
* Bird-watching towers
* Bird-watching hide
* Information and accommodation building
* Signs and information boards of the project

PUHTU-LAELATU NATURE RESERVE

Compiled by Tsipe Aavik

Puhtu-Laelatu Nature Reserve is situated on the western coast of West Estonian Lowland. It comprises a coastal chain of shallow inland bays (lagoons), several islets, coastal meadows, wooded meadows and woodlands. In 1939, part of the area was designated as the Puhtulaid Nature Reserve. This protected area was expanded to 4,900 ha with the establishment of the Virtsu-Laelatu-Puhtu Botanical-Zoological Reserve in 1959. Current borders were established in 1979. The wetlands of the reserve are important areas for different nesting, breeding and migrating bird species. Puhtu broad-leaved forest, Laelatu wooded meadow and Pivarootsi coastal alvars have been in the interest of scientists and nature protectors.

Estonian wooded meadows

Wooded meadows are one of the oldest ecosystems in the forest zone that have evolved through interactions between man and nature. These communities have offered means for living for more than a thousand years but nowadays they have disappeared almost from everywhere - only some tens of years has been enough for vanishing processes. The area of Estonian wooded meadows that has survived corresponds approximately to an area of wooded meadows that once surrounded one western Estonian village.

In Estonian agricultural literature the term 'natural meadows' is used, but in plant ecology these communities are known as 'semi-natural communities' (actually this term includes all the other traditionally managed grasslands and pastures besides wooded meadows – e.g. alvars, floodplain meadows, coastal meadows). An expression 'wooded meadow' is more common in scientific and specialised literature; local people mostly call these communities simply as 'meadows', 'woods', 'hay gardens' etc. Wooded meadows are sparse natural wooded stands with regularly mowed herb layer. In terms of appearance and ecological conditions, wooded meadows are similar to parks, yet they are considerably older and initially arose from natural communities. Groups of trees and bushes of different species composition may be sparse or dense, but the presence of turf is characteristic of wooded meadows. Mowing is usually done every year. Wooded meadows can be subdivided in several ways: dry and moist meadows, species-poor and species-rich etc.

Wooded meadows were widespread in the Baltic Sea countries, especially in Estonia, Finland and Sweden. Fewer and less typical wooded meadows could be found in Norway, Denmark, Germany and in the mountains of Central Europe. Flooded wooded meadows were common on the banks of larger rivers in Lithuania and Latvia.

The area of wooded meadows covered about 850 000 ha of Estonian territory at the beginning of 20th century. Wooded meadows started to disappear along with the abandonment of manual labour and agricultural intensification as well as collectivisation followed by Russian occupation. Mosaic landscape pattern characteristic to traditional Estonian landscape made through the changeover to monotonous intensive agricultural land. Extensive areas were meliorated to rise the production; less fertile meadows and peripheral areas were left fallow. But a wooded meadow that is not mown nor grazed may become overgrown already in 5-10 years.

About 4000 ha of wooded meadows in different conditions have survived up today. The future of those unique communities depends largely upon restoration and management subsidies. Wooded meadows represent a number of natural and cultural values why they need to be protected: unusually high plant species richness both on the ecosystem and micro-community level; habitats for many rare and endangered species; remarkable aesthetic value that is expressed in the diverse flora and fauna as well as in the characteristic heterogeneous appearance of half-opened landscape. Wooded meadows encompass the set of ancient agricultural traditions including former working methods, tools and celebrations related to agricultural activities. They serve an example of respective and wise attitude towards nature.

Laelatu wooded meadow

Laelatu wooded meadow is most probably one of the best-preserved and well-known wooded meadows in Estonia. The area has been used for hay cutting at least for 300 years. The area of the meadow is approximately 150 ha, but about 15-20 ha are mown nowadays. Because of the exceptionally high diversity of vascular plants, the area has gained the interest of botanists already since the beginning of the 19th century. The equipment of the research station enables to carry on several studies on ecology, geography and meteorology. There are study plots that have been investigated for tens of years. For instance, the long-time fertilisation experiment that was set up by Kalju Pork in 1961, has lasted already over 40 years. But many short-term experiments take place as well, organised by the researchers of the Institute of Botany and Ecology (Tartu University) and the Institute of Botany and Zoology (Estonian Agricultural University). The summer practice of plant ecology is carried out in Laelatu.

Laelatu wooded meadow is characterised by a high vegetation diversity and species density. Altogether 470 vascular plant species has been found from Laelatu and its' adjacent areas, 225 of which are specifically from wooded meadow. 76 vascular plant species has been recorded in a 1x1 m plot and 42 species in 20x20 cm plot. There are several reasons that lie behind the high species richness: 1) regular mowing for a longer period of time; 2) soil is neutral, calcium-rich; 3) environmental conditions are heterogeneous (shade and light conditions, wet and dry patches); 4) tree layer is species-rich; 5) large species pool.

Puhtu broad-leaved forest

Puhtu broad-leaved forest is situated on a former islet. Therefore the place-name Puhtulaid (or 'Puhtu islet' in English) still contains the word 'islet'. This geologically young area (ca 2000 years) was departed from the mainland by sea till the 19th century. The coastal areas of Puhtu islet have gained the interest of ornithologists. One of the most outstanding persons in the history of Estonian nature protection and science, Eerik Kumari, established here the research station of ornithology. In 1969 the laboratory of birds' ecophysiology was founded. Besides the significance of Puhtu in the history of natural sciences, there are also some interesting facts in the cultural history related to Puhtu. For example, the owners of Puhtu islet established a monument in the honour of German writer Friedrich Schiller in 1813; this is most probably the oldest monument in the world founded in the honour of Schiller that has survived up today. Jakob von Uexküll, the professor of Hamburg University and the founder of biosemiotics, owned the islet from 1928-1940 and spent most of his summers there. He also built a summer cottage that now houses the research station.

But botanists take interest in the unique broad-leaved forest of Puhtu islet. The forest has evolved under the impact of calciferous bedrock and warm climate influenced by the vicinity of sea. Basswood (*Tilia cordata*) and oak (*Quercus robur*) dominate the canopy accompanied by maple (*Acer platanoides*), ash tree (*Fraxinus excelsior*) and elm (*Ulmus glabra*). Lower layer comprises few rowans (*Sorbus aucuparia*), bird cherry trees (*Padus avium*), hazelnut (*Corylus avellana*), lilacs (*Syringa vulgaris*), common hawthorns (*Crataegus curvisepala*), honeysuckles (*Lonicera xylosteum*). The proportion of oaks is decreasing as the progenies are missing. The age of one of the most powerful oaks (perimeter 4.8 m, height 24 m) is supposed to be about 600 years. Liverworts (*Hepatica nobilis*), anemones (*Anemone nemorosa, A. ranunculoides*) and lung-worts (*Pulmonaria obscura*) dominate the ground layer in spring, followed by baneberries (*Actaea spicata*), dog's Mercuries (*Mercurialis perennis*), herb Paris (*Paris quadrifolia*). White-blossomed ramsons (*Allium ursinum*) adorn the ground layer in June. Besides, dropworts (*Filipendula ulmaria*), strawberries (*Fragaria moschata*) and lilies (*Lilium martagon*) have found a suitable habitat in the ground layer of the forest.

More information:

http://www.pky.ee/english/ - web-site of Estonian Seminatural Community Conservation Association

http://www.pky.ee/kirjutised/kirjutised.htm - overview of the bibliography of seminatural ecosystems publicised/written in Estonia

Luhamaa, H., Ikonen, I. & Kukk, T. 2001. *Läänemaa pärandkooslused. Seminatural Communities of Läänemaa county, Estonia.* Pärandkoosluste Kaitse Ühing, Tartu – Turku

Kukk, T. & Kull, K. 1997. *Estonia Maritima 2.* Publication of the West-Estonian Archipelago Biosphere Reserve (in Estonian, contains a brief summary in English)

SAAREMAA

Saaremaa (2672 square km) is the fourth largest island in the Baltic Sea after Sjaellandi, Gotland and Fyn. It is a low island with mostly flat relief. The western part of it differs from the rest of the island. Here the West-Saaremaa and Sõrve Uplands and the northern coast with its high escarpments are located. West-Saaremaa Upland is an approximately 50 km long and 25 km wide marginal formation of continental ice. Its maximum height reaches up to 54 m above sea level. Numerous coastal formations of water bodies (beach ridges, dunes and abrasion platforms), previously located in the same area as the current Baltic Sea, can be seen on the slopes of the Upland. Here coniferous forests are dominant.

Approximately 10 ancient earthen strongholds make the generally flat relief of Saaremaa more colourful. The diameter of Valjala, Kaarma and Kahutsi earthen strongholds is between 110 m and 150 m and the height of these earthworks which have been preserved up to the present day is 5–10 m.

The majority of the approximately 80 lakes of Saaremaa were formed as a result of surface uplift that has separated these water areas from the sea. A number of coastal lakes still have a connection to the sea. Most of these lakes (approximately 20) are located on Tagamõisa Peninsula in the northwestern part of the island, and on the southeastern and southern coast. Often the names of such lakes include "bay", "sea" or "bight". The largest coastal lake is a twin-lake, Mullutu-Suurlaht (14.4 square km), near Kuressaare. These lakes are halotrophic. Some coastal lakes dry out during the summer. Lake Karu (3.3 sqaure km), located in the forests of the West-Saaremaa Upland, with its sinuous coastline and numerous small islands, is considered to be one of the most beautiful lakes in Saaremaa.

More than ten thousand years ago the first parts of Saaremaa arose from the Baltic Ice Dam Lake. The uplift of the earth's crust is continuing even today - 2mm per year. The West - Estonian islands are lowlying plains resting on limestone, their average elevation being about 15 meters above sea level. Limestone has become denuded in a great number of places, resulting in cliffs, limestone pits and quarries at Mustjala, Ninase, Pulli, Uugu and Kaugatuma.

Because of its mild maritime climate and a variety of soils, Saaremaa has a rich flora, illustrated by the fact that 80% of the plant species found in Estonia are represented here. Altogether 1200 species of vascular plants can be found in Saaremaa. About 120 of the local plant species are rare ones which have received special protection status. The most famous endemic species is *Rhinanthus osiliensis* - a rare little flower growing mostly in spring fens. Orchids, rare and beautiful flowers are widespread: out of the 36 species found in Estonia, 35 of them are found on Saaremaa and neighbouring islands.

Over 40% of Saaremaa is covered with forests. They are mostly mixed forests but in some areas one can also find broad - leaved (deciduous), which are relict plant communities of former milder climatic periods. Wooded meadows were still common in Saaremaa before World War II, but many of these unique natural complexes have gradually become overgrown and thus turned into the ordinary forest.

The same is true for alvars (limestone areas covered with thin soil and stunted vegetation). Once a typical and exclusive landscape element in Saaremaa alvars are now in decline. Nature conservation planning for Saaremaa now includes protection of the largest and most unique alvar areas.

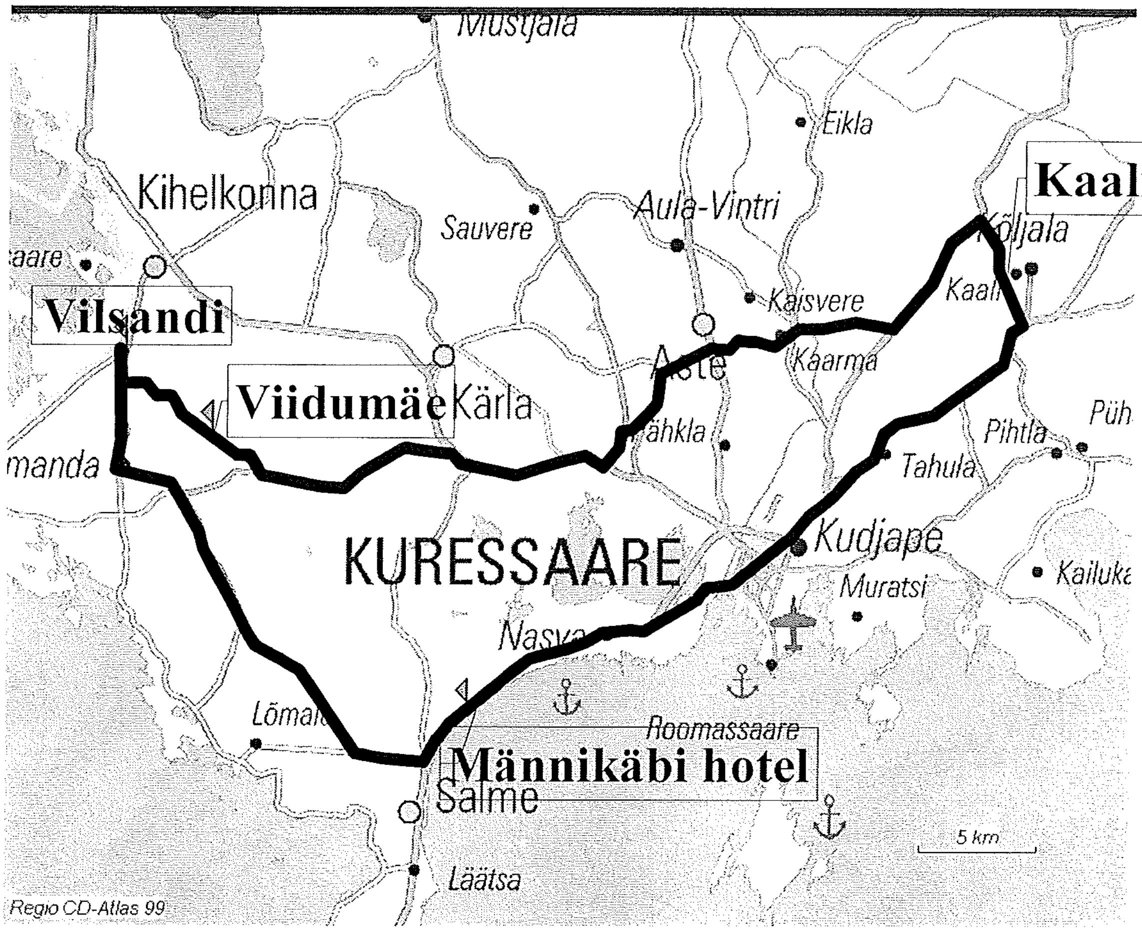
Saaremaa has a wide variety of rare wildlife species - ranging from insects to seals. The smallest protected wildlife species include *Cloude Apolle* butterflies and Roman snails. The coastal areas of Saaremaa are famous seal habitats. The gray seal which is common here can be found in three large permanent resting areas on the islets off the coast in the western and southern parts of Saaremaa. The local population of grey seal is slightly increasing Ringed seals can also be encountered everywhere in the coastal waters of Saaremaa, but because of their timidity it has not been possible to make an estimation of their number. Our islands lie within the East - Atlantic flyway, which is the migration path of waterfowl. This "bird - road" connects North - eastern Europe with arctic regions and each year hundreds of thousands of migratory birds visit Saaremaa in spring and autumn. The barnacle goose, mute swan, whooper swan, eider, shelduck and a great many other bird species have been given protection status. But on the whole, the islands are somewhat poorer in wildlife species than the mainland. Neither mole, mink, nor otter can be found her, the lynx and the brown bear are but infrequent guests.

Dolomite, limestone, curative mud, mineral water, sand and gravel, ceramic clay are the major local minerals.

Saturday
28 August

Kaali meteoritic crater - Viidumäe Landscape Reserve-
Vilsandi Landscape Reserve

Saturday, 28.08.04



THE BIOLOGY AND SPREAD OF SAND PINK (*DIANTHUS ARENARIUS* L.) ON JÄRVE-MÄNDJALA DUNES

Krista Takkis
Saaramaa's Co-Educational Gymnasium
Form XI

Supervisors: Inge Vahter, Mart Mölder
Saaremaa's Co-Educational Gymnasium

Sand pink is a very decorative plant. There are two subspecies of sand pink in Estonia: *Dianthus arenarius* L. subsp. *arenarius* and *Dianthus arenarius* L. subsp. *borussicus* Vierh., which can not be easily distinguished. *Dianthus arenarius* L. subsp. *arenarius* is also put into the II and IV annex of the Habitats Directive. On the research area, Järve-Mändjala dunes, grows only one subspecies - *Dianthus arenarius* L. subsp. *arenarius*.

In the theoretical part of the research, a review of the systematic belonging of the sand pink and its subspecies was presented, as well as its names in different languages and the other representatives of *Dianthus* family in Estonia. A review was also made of the biology of sand pink and its spread in Europe and in Estonia. There was also a survey made of endangering factors and protection, requirements on growing areas and accompanying species.

The purpose of the practical research was to examine the growing areas and spread of sand pink on Saaremaa Järve-Mändjala dunes in the summer of 2002. During the research it was explored how the human activity in the tourist area affects sand pink, how is it influenced by afforesting and what is the general situation of the subject of the research on the explored area. For that, 35 test (or analysis) squares were marked on the ground, which formed a transect in which the general and sand pink coverage, and the accompanying species were examined, and different morphological researches were made.

On the ground of received results, the possible connections were clarified and they were compared to those found in literary sources.

The main accompanying species of sand pink proved to be our-lady's bedstraw, which was found in 32 squares, and mountain gold (in 27 squares). A herbarium was put together from the accompanying species of vascular plants (33 different species), a collection of mosses (3 species) and lichens (7 species). Altogether on the research area there were registered 45 vascular plant, 7 moss, and 7 lichen species. On the average, in one analysis square there were 7,3 accompanying species.

It turned out that sand pink does not prefer to grow on the unfixed sand, but can tolerate it successfully.

The main endangering factors are excessive trampling, afforesting, construction works, and butterfly caterpillars.

Moderate trampling is actually good for sand pink, but excessive trampling is harmful. Sand pink prefers to grow on treeless areas, it does not appear in woods in tree shades.

On the research area the general condition of sand pink is good, the population is vital and stable. On this area sand pink is being registered since 1855. Nevertheless, it should be observed and the research should be continued. Sand pink should be investigated everywhere in Estonia because there is still much unclear about it and as the two subspecies are hard to distinguish, more attention should be paid to that as well.

KAALI METEORITE CRATERS

Eighteen kilometers from Kuressaare towards Kuivastu is the location of Estonia's most unique geological object, Kaali meteorite craters. 9 meteorite craters are located on the 50-ha territory, 58° 24' N, 22° 40' E, of the only Estonian geological reserve: the main crater and 8 collateral craters.

In the main crater there is a natural body of water that is known as Lake Kaali. Its diameter, ranging from 30 to 60 meters, depends on the water level. Its depth is one to six meters. The lake is fed by ground water and precipitation. The bottom sediment layers are about six meters thick and up to 4 000 years old.

Early explorers considered the ring-shaped Kaali crater as a volcanic depresion or a karst hole formed due to the dissolution of limestone, gypsum or salt. The meteoric origin of the lake basin was first suggested by J. Kalkun-Kaljuvee in 1922. In 1937 Ivan Reinvald collected 30 fragments of meteoritic iron from the collateral craters. The analysis of the fragments showed that the cosmic body which fell to the Kaali area belonged to the most frequent type of iron meteorite, coarse octahedrite, with the contents of Fe and Ni amounting to 91.5 and 8.3%, respectively. The scientists assert that the meteorite with the initial mass 400-10.000 tons, entered the atmosphere from the Northeast direction with the initial velocity 15-45 km/s, at impact its velocity was 10-20 km/s and the initial mass of the meteorite could have been 400 to 10 000 tons, mass at impact was 20 to 80 tons. At the altitude of 5-10 km the meteorite broke into pieces and fell to the Earth in fragments as a meteorite shower, the greatest of which produced a crater with a diameter of 110 m, 22 m deep, and 8 smaller ones with diameters 12 to 40 m, depths varying from 1 to 4 m.

The first archaeological finds from the eastern wall of the main crater were discovered by Ülo Kestlane, a researcher in the Institute of Geology, in 1975. In 1976 the archaeologist Vello Lõugas started archaeological excavations. On the external slope of the North-eastern part of the crater wall a stronghold was discovered. On the lake side it was protected by the steep bank, on the other side a mortarless limestone wall, 110 m long and 2 m wide, had been erected.

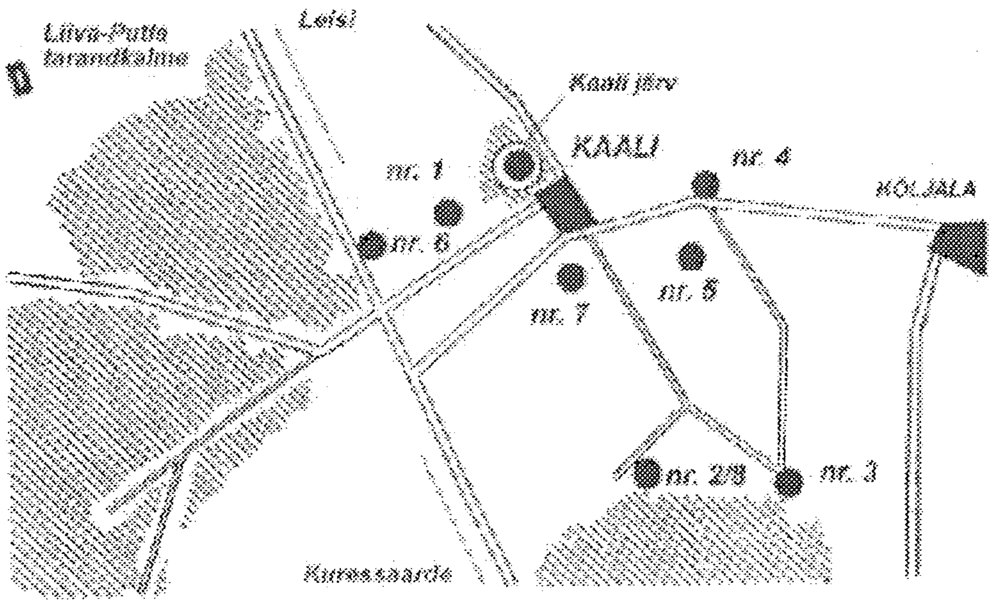
The craters or their embankments do not contain marine sediments. Therefore the craters cannot be older than the time the area emerged from the sea. The explosion scattered into the air abundantly fine particles of soil and rock, which by melting formed glassy spherules. These spherules have been found in mires and lake sedimets in the vicinity of the craters. The age of the layers of peat with microimpactites is 7500 to 7600 years, which is the most probable age of the Kaali craters.

But there are two other versions about the date of the falling of the Kaali meteorite.

The main crater of Kaali is a typical explosion crater. The meteorite falling at cosmic velocity exploded when it collided with the earth, and created the crater with a surrounding mound of uplifted bedrock. The meteorite itself pulverized in the explosion and dispersed in the rising cloud of dust. Hereby, no meteoritic fragments preserved in the main crater.

The smaller craters, locally known as dry lakes, are shallow bowl-shaped hollows. However, vague and in some cases interrupted mounds can mostly be traced on the banks of the secondary craters. Hazel thicket grows in most of the dry lakes. These are impactcraters and meteorite fragments were gathered in them.

Kaali crater can be compared with the world's best known and youngest craters.



It is not impossible that there are as yet undiscovered meteorite craters. Since the meteor fell as a meteor shower, this is probably more than likely. But the smaller depressions have been filled with rocks and soil by the local farmers, and they have melted into the landscape.

Kaali lake also has an important place in tradition. It was also known as Holy Lake and there is archaeological evidence that it was a place of offering for many centuries. The exclusiveness of the main crater is also accentuated by a mysterious massive stone wall surrounding it during the early Iron Age, (600 B.C. to 100 A.D.). The wall, 470 m long and 2.5 m wide, surrounding the main crater is far mightier than the mightiest stone fences of Saaremaa. The stones in the wall were very big – their diameter was up to 1.5 m. The aim of such powerful and labour-intensive construction had to be different from that of an ordinary stone fence. Probably its function was to separate the important cult site from the surrounding world, so that no unwelcome guest could approach it.

The fall of the giant meteorite was certainly a tragic event, probably accompanied by extensive demolition, fires and even human victims. Falling of heavenly fire, explosion, clouds of dust and smoke, and the landscape changed beyond recognition must have caused fright and horror and awe among the surviving inhabitants. Lennart Meri has analysed the possible reflections of the Kaali catastrophe in human recollections in his books "Hõbevalge" and "Hõbevalgem", connecting Saaremaa with the mythical Thule, supposedly visited by the Greek traveller Pytheas in 325 BC, and also with the place of worship of the Germanic goddess of land, Nerthus, described by Tacitus. Besides the written sources, the falling of the Kaali meteorite was indubitably reflected in the folklore and mythology of several peoples. The falling of Sun from the sky, which, depending of the location of the observer, could occur altogether in the wrong quarter of the horizon, the terrible crash, the all-demolishing impactwave, the cloud of dust and forest fires indubitably left a deep impression in the people of that time. Several verses of the Finnish epic "Kalevala", the ancient Germanic "Older Edda" as well as in the folklore of Estonia and the neighbouring peoples indicate that impression.

The ancient Greek myth about Phaeton, the son of Sun, who, driving the solar chariot, lost the power over the horses and tumbled into the mysterious river of Eridanos, also leads one's thoughts to the Kaali catastrophe.

VIIDUMÄE NATURE RESERVE

Viidumäe Nature Reserve (18.7 square km), located in the south-western part of West-Saaremaa Upland, was established in 1957 in order to protect rare plant species and plant communities. Viidumäe is located on Saaremaa's highest point and, geologically speaking, its oldest place, Saaremaa's backbone which started rising from the sea about 10 000 years ago. The preserve is 7.5 kilometres long and 700 to 800 meters wide, and covers 7 873 hectares.

A scarp of the Ancylus Lake, a stage in the evolution of the Baltic Sea, the maximum height of which is 18 m and where the slope grade in some places is 25°–30° runs along the territory of the Nature Reserve. Due to the diverse natural conditions, the Nature Reserve is extremely rich in plant species. Although the area is relatively small, very many different species of plants, mushrooms and animals can be found here. The area is divided into two separate zones. The higher areas are dryer, whereas the lower areas are boggier. Additionally, thanks to Saaremaa's softer maritime climate, approximately 700 species of vascular plants can be found here, and of these 58 are designated as protected species, including Saaremaa yellow rattle (*Rhinanthus osiliensis*), a plant that was discovered here in 1933 and thus far has only been found on Saaremaa. Over 630 species of butterflies have been counted. The occurrence of pine groves with oak underwood is not common in such climate conditions and is, therefore, rare in Estonia. Swamps and bogs cover about 10% of Viidumäe. Almost 85% of Viidumäe is covered in forest. Various forest types are represented. The oak forest with pine undergrowth, the so-called Sutru forest, is considered to be a relic of the times when the climate here was much warmer.

Meadows cover a relatively small area. Here on the meadows and in the broadleaf forests is where one can find Estonia's largest snail, the vinyard snail (edible!). Viidumäe wooded meadows are still mowed each summer, in an effort to maintain a piece of cultivated landscape that was at one time common thought Saaremaa.

Viidumäe's highest point is Suurmägi (Big Mountain), which rises to 54 meters above sea level. There is a watchtower on top, from where one can get a good view of the countryside. The administrative centre is at Audaku, where there is a small botanical museum. In order to protect the many rare plant species here, it is forbidden to travel outside the marked roads without special permission.

VILSANDI NATIONAL PARK

The first protected area in the Baltic countries, Vilsandi National Park, is located near the western coast of Saaremaa. The Vaika islands near Vilsandi, rich in bird species, were designated as a protected area already at the beginning of the 20th century. The territory of the protected area has increased over the years and in 1993 a national park was established here. In 1997, Vilsandi National Park was designated as a wetland of international importance. The National Park encompasses Vilsandi Island, the western coast of Saaremaa and approximately 160 small islands with total area of 182 square km (of which the sea area forms 105 square km). In addition to its original objective, i.e. protection of bird species, the current task of the National Park is also to preserve coastal and sea landscapes and species-rich vegetation of West Estonia. More than 250 bird species have been registered in the National Park, of which 112 species breed. Eiders are the most numerous (more than 4000 pairs). During the migration period, flocks consisting of thousands of birds (barnacle geese, eiders and other waterfowl) use the area as a stopping rest site.

Loona Manor

A road bordered with stone fences leads us to Loona Manor, located to the west of the Lumanda-Kihelkonna road. The manor house has a long and complex history. The oldest parts of the building date back to medieval times. At the beginning of the 19th century, the manor house evolved into a building of good proportions and beautiful details characteristic of Classicism.

The manor complex also includes a stone granary, a garden house and a park. After WW II the buildings fell into disrepair. Since 1996, the manor has been administered by the Ministry of Environment. Today, the main building has been restored and serves as the Visitor's Center for Vilsandi national Park.

Not far from the manor there is an old coastal settlement which dates back to the second millennium B.C., the transitional period from the Stone Age to the Bronze Age. Potsherds of the comb and corded ware cultures have been found, as has hunting of sea mammals, mostly seals.

Stonewalls in Saaremaa

Helean Täht

Saaremaa's Co-Educational Gymnasium

Stonewalls have had many roles in the lives of men. They have been used to border homejards, fields, cattle - and hayfields from wondering animals. Stonewalls were built so many because of rocky soil and shortage of wood. Theyr building was very precise and hard work, there have been even wallsmiths. Large part of the stonewalls have lost their elementary function for the moment but they are quite pleasing with their thick carpet of moss.

Three Karalas stonwalls were took under exsamination where species of plants and mosses were determined and compared. Stonewalls were picked on their built, age and mosscoverage to compare differences of the plants that grow on them. Plants were picked from the beginning of summer in 2002 to end of the summer in 2003 and determinaton of their species took place mainley in winter. From the stonewalls were found 20 species of mosses, 5 species of lichen and more than 10 other species of plants.

There were more mosses on ironstones then on slatestones. Most common moss was *Homalothecium sericeum* that was on all of the stonewalls. Most rare moss was *Orthotrichum cupulatum*. Lichens were most common on stonewalls that were in clearings. Mosses mainley liked to grow near trees. Most off the mosses found on stonewalls were ***mesophytes***.

Kolga stonewall was the richest in moss-spiecies, the poorest was the highest stonewall. I found flowering plants onley on the oldest wall.

The goals of the research were fullfilled.

LINKS ABOUT ESTONIA

http://visitestonia.com/

http://www.estonica.org/index.html

http://www.einst.ee/