Vegetational History of Lake Maardu Sediments based on the Pollen Stratigraphy

Abstract

The vegetation around Maardu has been strongly influenced by man. Alnus thickets and Filipendula ulmaria – Urtica dioica wastelands prevail in the present landscape. Since 9500 BP (uncal.) an open landscape of the Betula heath type has gradually changed into more closed forest types with the light demanding species Juniperus, Populus, Salix and Hippophae vanishing and making room for Alnus, Ulmus and Corylus. Alnus invaded the area very quickly at the beginning of the Boreal, obviously forming a belt along the lake shore. The dense Alnus stands acted as a «curtain». This was evidently also the most important pollen trap for NAP pollen, as from this time onwards the NAP pollen values are less than 7% and have the opposite configuration to those of Alnus. The empirical lower limit of Picea is dated to 6495 ± 60 BP (Saarse et al., 1990). A sample taken just above the Ulmus decline has been dated to 4365 ± 75 BP. Some factors possibly indicating an opening up of the Atlantic forest in the region already occur before the drastic Ulmus decline at a depth of 2.25 m. The Corylus, Picea and Quercus pollen curves rise together with some scattered finds of light-demanding Helianthemum, Calluna and Scorpiulariaceae. This shows a tendency for open spots to develop in the Atlantic forest canopy. Picea and Quercus reach their culmination in the Sub-Boreal, while Ulmus makes way for Betula and Pinus. Fraxinus still holds its Atlantic position, but considerable opening up of the forested landscape is indicated. The first cereals (Triticum-type) are recorded around 3800 BP, followed by Plantago lanceolata and other human indicators. A reforestation of the lake shores is observed around 2960 ± 70 BP, shown in the pollen diagram as a peak in Alnus and Humulus-types, the latter being thought to have grown as a liane in the Alnus forest under natural conditions. A simultaneous decrease in a number of light-dependant weeds and a lower amount of charcoal dust argue for this as well. This short phase is then followed by a rapid deforestation period, with agriculture present in the region. Hordeum and Secale appear, as do grains of the Cannabis-type. Gradually the landscape takes on the features visible at the site at the present day.
INTRODUCTION

The surroundings of Lake Maardu are extremely interesting for Estonian cultural history, with the oldest settlements dating back to the Early Neolithic period (Lõugas, 1992; Lang, 1992; Lang, 1995, this volume). This report tries to solve some of the problems of the regional vegetation history using most up-to-date pollen analysis methods, which until recently had only been employed sporadically in Estonia (Saarse and Königsson, 1992). General information on the Maardu area and data regarding the sediment stratigraphy are available in Saarse et al. (1995, this volume) and Veski (1992).

MATERIALS AND METHODS

A 5.35 m sediment core was taken from the central part of Lake Maardu in 1991 (Saarse et al., 1995, this volume). 1 m columns were wrapped in plastic film and transported to the laboratory for closer examination and sampling. Each cm was sampled separately and the samples were treated by the acetylation method described by Erdtman (1936). Minerogenic samples were left in hydrofluoric acid for some days. Routine pollen analysis was carried out using a magnification of 250 x, and all critical determinations were made using 1000 x magnification supported by phase-contrast and a reference collection. At least 1000 arboreal pollen grains were counted at each level.

The pollen diagram for Lake Maardu (Fig. 1.) was plotted with the TILIA-TILIA*GRAPH computer program (compiled by Eric C. Grimm, 1991). Calculations were based on the pollen sum, P = 100 %. The destruction degree curve summarizes all corroded pollen of Betula, Alnus, Corylus, Ulmus and Tilia.

The hatched silhouettes show the pollen percentages and the white silhouettes the same percentages at an exaggeration of 5 x.

The pollen diagram from Lake Maardu is divided into 10 local pollen assemblage zones (PAZ’s).

RESULTS

The Lake Maardu pollen diagram is characterized by a high level of Alnus pollen, low values of NAP pollen in the middle part of the stratigraphy and excellent pollen preservation.

Zone 1. Betula-Pinus-Hippophae (535-525 cm). – Pinus has fairly high values in this zone, from 18 % at the beginning to 23 % in the upper part. Betula acts in the opposite way, showing higher values (47 %) where Pinus is low and reaching maximum values at the end of this zone (56 %). Ulmus and Corylus both have low values at the beginning, but their curves rise continuously, although remaining below 5 %. Alnus has its lowest values in this zone (generally less than 1 %). Only in one analysis does its curve rise over
Fig. 1. Lake Maardu pollen diagram, selected taxa only.
5%, to fall again in the next. Of the other trees, some Quercus, Fraxinus and Picea pollen is recorded. Populus reaches a maximum of 2% in the lower part of the zone, but decreases rapidly upwards, and the same tendency is seen among the bushes: Salix, Juniperus and Hippophae having higher values in the lowermost analysis, but decreasing towards the upper zone boundary. This zone is also characterized by comparatively high NAP values (21%), which decrease to 16% at the upper boundary. Cyperaceae, Ranunculaceae and Filipendula reach their highest values in this zone. Pollen of aquatic plants shows a wide variety and occurs in considerable quantities. The same can be said of the spores of Equisetum, Polypodiaceae and Sphagnum. The degree of destruction, numbers of fungal hyphae and amounts of charcoal dust are high.

Zone 2. Betula-Alnus-Ulmus (525-470 cm). – The Betula curve shows a decrease from 56% to 28%, but still has higher values than anywhere later in the diagram. The Alnus curve has a rapid rise from very low values to the absolute maximum, while that of Pinus decreases to 10% in the upper part of this zone. The Ulmus curve reaches 10%, but Corylus still has low values, reaching over 5% only towards the upper limit of the zone. The Salix curve starts with higher values (2-3%), but soon decreases to 0.5%. Low values are recorded for Quercus, Fraxinus and Populus. Scattered grains of Juniperus, Hippophae and Tilia are observed. The empirical curve for Picea starts towards the upper boundary of this zone. The NAP curve decreases rapidly from 16% in the lower part of the zone, and stabilizes around 10%. The graph for the Humulus-type starts at the bottom of the zone. No aquatics are observed at the lower border of the zone.

Zone 3. Betula-Alnus-Corylus (470-419 cm). – The Betula curve fluctuates around 25-30% and that for Alnus now has comparatively low values following its maximum. Pinus remains under 10%. Corylus rises rapidly to 15% and shows a decrease after that, while Ulmus rises to 15% in the upper parts of this zone. The empirical limit of Tilia lies at the bottom of this pollen zone. NAP has low values of 6.8%. The degree of decomposition increases slightly during this zone.

Zone 4. Betula-Alnus-Ulmus (419-341 cm). – The Betula and Pinus curves have similar trends, starting from lower values at the bottom of the zone, reaching higher ones in the middle part (34% and 13% respectively) and decreasing more or less drastically towards the upper boundary (Betula to 18%, Pinus to 8%). The Alnus graph shows the opposite tendency. Ulmus still has a rising curve, to reach its maximum just below the upper zone boundary (17-18%). Corylus recovers from low values at the bottom of the zone and increases rapidly to an absolute maximum of 20%, whereas the Salix curve decreases to minimum values towards the upper zone limit. The first scattered pollen grains of Acer are recorded in this zone. The NAP curve remains at low values of around 6-7%.

Zone 5. Fraxinus-Ulmus-Corylus-Alnus (341-290 cm). – The rational limits of Fraxinus, Tilia, Quercus and Picea occur simultaneously at the lower border. Fraxinus increases rapidly to its maximum of 5%, while Picea, Quercus and Tilia are present at low values. Alnus holds its own, as does Ulmus, which is still high although decreasing somewhat. Corylus decreases towards the upper zone border, and Salix reaches its absolute minimum. The NAP curve fluctuates gently between 5 and 7%.

Zone 6. Tilia-Ulmus-Fraxinus-Alnus (290-190 cm). – Betula reaches its minimum of 16% in the lower part of this zone, but recovers higher up although still showing low values. The same may be said of the Pinus curve, which increases slightly towards the upper zone boundary. The Alnus curve is high and rising, reaching 36% at the upper boundary. Tilia shows uniform high values throughout, while Ulmus first decreases constantly from 15% to 10% and then drops to 4% at the upper zone boundary. Quercus has steady low values with a gentle rise further up, and the same is true of Picea. The first Carpinus pollen is recorded in this zone. Corylus decreases upwards, before assuming
distinctly higher values around the upper zone boundary. *Juniperus* shows a marked peak at a depth of 230 cm which coincides with an increase in the degree of destruction and a slight rise in the NAP curve. More frequent representation of *Calluna, Rumex, Ranunculus* and light-dependant NAP can be observed around this level.

Zone 7. *Picea-Quercus* (190-121 cm). – The zone is characterized by maximum values for *Quercus* and *Picea. Quercus* reaches its maximum, of 7%, before *Picea* does and then decreases steadily towards the upper zone boundary, although still with comparatively high values. *Picea* has a distinct maximum of 14%. *Alnus* decreases from around 36% at the bottom to 25% in the upper part of the zone, while *Betula* shows a steady rise from 15% to 34%. The *Pinus* curve rises to 13-14% during the first analyses in this zone, but remains at that level upwards. *Ulmus, Tilia* and *Corylus* decrease, whereas *Juniperus* and *Salix* show higher values towards the upper zone boundary. *Acer* and *Fagus* pollen are more frequent, and the rational curve for *Carpinus* starts at the upper boundary of this zone. The NAP curve rises from 4% at the lower boundary to 6% at the upper one. The first pollen grains of *Cerealia* (Triticum-type and *Avena*-type) are recorded at the level of 160 cm, and *Plantago lanceolata* appears a little further up. *Artemisia* and *Filipendula* show higher frequencies, pollen of *Mesium*, *Hellanthemum* and Chenopodiaceae is observed at the lower boundary of the zone. Still higher values of charcoal dust are recorded (11%).

Zone 8. *Alnus-Betula* (121-91 cm). – The zone is characterized by a distinct peak in *Alnus* and a simultaneous decrease in *Betula* together with *Salix, Juniperus, Cerealia, Rumex acetosella*, *Filipendula, Artemisia* etc. and a fall in the charcoal curve. The *Alnus* curve drops drastically to 17% and *Betula* recovers to 36% at the upper zone boundary. NAP rises from 6% to 15% in this zone, mainly due to the increase of the Poaceae pollen. A marked peak in the *Humulus*-type curve occurs at the same level as that of the *Alnus* curve. The *Pediostrum* curve has low values.

Zone 9. *Betula-Pinus* (91-51 cm). – The *Betula* curve has high values (35%), but decreases towards the upper zone boundary (28%), while the *Pinus* graph rises, and more distinctively so in the upper sequence, but does not reach 20%. The *Alnus* curve has comparatively low values, around 17-20% and the *Picea* curve is uniform and below 5%. *Quercus, Tilia* and *Fraxinus* are low and decreasing, while *Corylus* ranges between 2-3%. The *Juniperus* curve rises to 2%, *Carpinus* pollen is present throughout the zone, and the NAP curve fluctuates around 15-17%. The first pollen grains of the *Cannabis* and *Secale*-types are recorded at the lower zone boundary. The curve for the degree of destruction shows a rise.

Zone 10. *Pinus-Betula* (51-0 cm). – The *Pinus* pollen curve increases from 18% to 27% in this zone and *Alnus* and *Betula* decrease at the same time, although the latter increases again in the uppermost analyses. *Salix* also shows a rise in an upward direction. One pollen grain of *Hippophae* is recorded at a depth of 10 cm. The NAP curve reaches its highest values, around 27%, but decreases towards the surface. The greatest variety of taxa are still observed in the uppermost samples. A distinct, very high peak in fungal hyphae is recorded in the zone, together with maximum values for charcoal dust. The degree of destruction is also high.

**DISCUSSIONS AND CONCLUSIONS**

The vegetational history of a landscape is determined by a variety of conditions, often contradictory ones, occurring in the same time interval and influencing the final representation of pollen grains in the diagrams, and in
more recent times human beings have also played a significant role in changing the contemporary landscape. Thus it is difficult to connect variations in pollen diagrams with any one single event in the environment, although such effects are always open to discussion.

Fieldwork and visual inspection of the lake sediments did not lead to the discovery of any hiatus in the sedimentation, but pollen analysis accompanied by the other methods described here revealed a hiatus in the stratigraphy.

Three samples from below the sandy gyttja were analysed palynologically, but without success. The sand contains practically no pollen grains.

Zone 1. Preboreal. – According to the $^{14}$C dates organic sedimentation in the Lake Maardu basin started approximately 9500-9600 years BP (uncalib.) (9490 ± 110 y BP Ua-2390, Possnert, unpublished; 9655 ± 70 y BP Thn1313, Saarse et al., 1995, this volume). The high values for Betula pollen together with the light-demanding Juniperus, Populus and Hippophae suggest a rather open landscape with Betula as the dominant tree species. According to Berglund (1966), a more or less heath type of Betula forest spread to the region at that time. The presence of Pinus at this date is widely discussed. Aario (1940) demonstrated the over-representation of Pinus pollen which occurs in open areas, but Berglund (1966) does not exclude the possibility that scattered stands or trees of Pinus could have existed in southern Sweden, using finds of Pinus stomata as indicators, for in contrast to Pinus pollen, which could be transported over long distances, the stomata must refer to more local Pinus stands. As Pinus stomata have been recorded in this zone, and since the lake has no inlet which could have served as a transport medium for them, there must have been pines standing close to the lake at that time. Nevertheless, most of the Pinus pollen is considered to have been the result of long distance transport. The rather high Salix pollen values could be explained by stands of dwarf-shrub species (Andersson, 1895, cited by Pålsson, 1977) possibly growing in a narrow belt around the lake. Artemisia, Chenopodiaceae, Gramineae and Thalictrum type are represented by markedly high values, indicating the persistence of late-glacial communities on calcareous soils with low competition from other plants (Pålsson, 1977). A find of Rubus chamaemorus pollen indicates some open peat bogs or fens near the lake. The constituents of the NAP curve indicate a relative absence of overshadowing trees.

The aquatic vegetation is represented by the true limnic species Myriophyllum spicatum, M. verticillatum and Potamogeton and telmatophytes such as Menyanthes and Polygonum amphibium type, of which M. spicatum is considered to be eutrophic (Fries, 1951). The supposed hiatus between PAZ’s 1 and 2, which seems to correlate with the end of the Pre-Boreal and the beginning of Boreal could have been caused by a regressive stage in the Baltic basin. An isolation of the Lake Maardu basin took place during the Yoldia Sea regression, probably forming a closed, shallow basin which periodically dried up as a result of seepage through the rather coarse sandy material underlying the lake basin. Such a dry period is supported by the presence of fungal hyphae and a higher degree of destruction. The continuation of sedimentation was brought about by the Ancylus transgression and the associated rise in groundwater level. The latter could also have led to sediment erosion and have thus ended with a hiatus in the stratigraphy. There is no evidence in the Lake Maardu sediment stratigraphy that the Ancylus Lake waters reached its basin directly, although freshwater diatoms typical of the Ancylus stage (Navicula scutelloides W. Sm., GyrOSPIMA attenuatum (Kütz.) Rabh., Achnaethes clevei (Grun.) are recorded in large numbers at a depth of 5.23 m and upwards (Sakson, 1995, this volume). Their rapid increase also supports the idea of a hiatus. A possible shallow connection
between the Ancylos Lake and Lake Maardu could have existed over the low-lying areas west of the present lake.

Zone 2. – The very high and quite uniform Alnus pollen curve throughout this zone is thought to be due to the «curtain effect» of the Alnus belt along the lake shore (Thomson, 1937). This was evidently also the most important pollen trap for NAP pollen, as from this zone onwards the NAP pollen values are less than 6-7% and have the opposite configuration to that of the Alnus curve. The pollen of other species is therefore to a great extent dependent on the density of this belt. Some fluctuations in Alnus frequencies could be explained by changing climatic and hydrological conditions. As the lake shore is low-lying, the Alnus belt may have suffered during more humid periods, opening the way for pollen rain from slightly more elevated habitats, or for the long distance transport of Pinus pollen grains. The low frequencies of Salix, Populus and Juniperus support this idea, whereas the finds of extremely light-dependent Hippophae pollen grains indicate that at least some patches of open virgin soils existed nearby, probably on the shore, as the Artemisia and Filipendula pollen curves also retain their previous frequencies. Of the broad-leaved trees, only Ulmus is represented frequently, occupying the best soils in the area, namely on the beach ridge north of the lake, together with Corylus. The rather high Ulmus pollen values could be explained by Ulmus being one of the constituents of the ring of trees growing next to the lake shore.

Zone 3. – A rapid influx of Pediasstrum simplex suggests a change in the lake ecosystem (Veski, 1994). A higher groundwater level may have affected the Alnus curtain, restricted the Ulmus expansion, preserved suitable habitats for Hippophae, Artemisia and Chenopodiaceae and provided better pollination conditions for Corylus.

Zone 4. – The pattern of tree pollen percentage changes is quite difficult to explain. On the one hand, the rising Betula curve could mean more humid conditions in which Alnus would have suffered in the lower areas and the coastal belt would have been more open to the long-distance transport of Pinus pollen. This idea is supported by increased Juniperus and lower Ulmus values. Filipendula frequencies are also higher, which, bearing the habitats of Filipendula ulmaria in mind, is also suggestive of moist conditions. On the other hand, humid conditions could favour the vegetation in this semicontinental area. More favourable climatic conditions occur in the upper part of this zone, and Ulmus increases, most probably at the expense of Betula. The Alnus belt recovers and Pinus frequencies become fairly low. Before the overshadowing by broad-leaved trees starts, Corylus has a maximum simultaneously with Ulmus. From this point on Corylus is not able to produce pollen properly in the shade of the widely spread Quercetum mixtum. Insect pollinated Acer is present in this zone and seems to have been growing in the vicinity, as the pollen frequencies of this tree species does not reflect its actual proportion in the vegetation.

Zones 5 and 6 – The optimal climatic conditions in the Holocene are observed in these zones, and most of the area is covered by broad-leaved forest.

Zone 5. The lower boundary of this zone is well defined by simultaneous rises in Tilia and Fraxinus and the continuous curves of Quercus and Picea, together with the lowest values in the Pinus and Betula curves. All the broad-leaved trees are present in the area. Fraxinus, the pollen frequencies of which were low during the previous zone, spreads rapidly at the expense of Ulmus, which shows a declining tendency. Tilia expands more slowly. Picea is thought to have been growing in the area, but being a bad pollen producer under shaded conditions, its curve is low although continuous. The 14C date of 6495 ± 60 years BP (uncal.) (Saarse et al., 1990) obtained for the lower Picea limit gives an idea of the approximate time of appearance of this species in the forest.
Zone 6. Atlantic 2. – *Ulmus*, *Corylus* and *Fraxinus* become overshadowed by *Tilia*, which expands at the expense of the other broad-leaved trees. *Tilia* is insect pollinated, and thus under-represented in the pollen diagrams. An opening in the mixed forest is interpreted as having taken place in the second half of this zone, together with an increasing input of terrigenous material into the lake, according to mineral magnetic analyses (Sandgren, 1995, this volume). The upper boundary of the zone is drawn at the *Ulmus* decline, which has been a topic of discussion for many decades. Iversen presented his classical land-nam theory in 1941, but modern theories have explained the *Ulmus* decline alternatively as a result of climatic change or an elm disease combined with browsing and resulting in an ecological collapse. It may also have been due to a combination of climatic changes and cultural influences. In any case the opening of the forest enabled *Corylus* to flower more prolifically. The *Ulmus* decline around Lake Maardu is dated to 4365 ± 75 years BP (uncal.). This sample was taken from above the decline (190 cm), however, so that taking the sedimentation rate into account the beginning of the drastic decline can be calculated to have occurred around 4550 BP (uncal.). Elsewhere in N. Europe the *Ulmus* decline is placed at 5150 BP (Berglund, 1991).

Zone 7. Subboreal. – The fact that the *Ulmus* decline is very distinct in this area suggests that the *Ulmus* stands must have been thoroughly disturbed. It is thought that man was present in the area before the actual *Ulmus* decline, which probably indicates the power of contemporary man. The *Ulmus* decline induced by climate deterioration had started earlier (probably in zone 6). The chain reaction described by Nilsson (1948) is then thought to have taken place. The climate changes affected the established forest, but also forced contemporary man to gather fodder from the *Ulmus* trees so that the relative openness of the resulted forest created better conditions for *Corylus*, *Quercus* and *Picea* to produce pollen. The increase in light-demanding NAP species also suggest a more open landscape, as do the irregularly higher frequencies of *Fraxinus*, *Juniperus* and *Salix*, so that it is likely that the *Alnus* belt around the lake was broken. The first *Cerealia* and *Plantago lanceolata* are recorded in the middle of the zone, and the NAP values rise continuously. The agricultural history of the area around Maardu shows a gradual succession of different cereal types, for although the low-lying areas around the lake were not suitable for large-scale agricultural development, the nearby alvar landscapes provided suitable conditions for growing crops, and it is in this area the first permanent «Celtic» fields in Estonia are to be found (Lõugas, 1992; Lang, 1995, this volume; Veski and Lang, 1995, this volume).

Zone 8. – A decrease in light demanding bushes and NAP, or even the disappearance of these, is dated to 2900 ± 70 BP (uncal.), when the input of terrigenous material into the lake was low. The reason for this could be either a climatic change or less human activity in the region, but one is inclined to favour the former explanation. The post-Litorina stage of the Baltic started about 3000 years ago, with a climatic deterioration (Sernander, 1926, cited in Brumberg *et al.*, 1984), possibly on account of the more humid climate and abundant vegetation as suggested by the simultaneous rise in the *Alnus* and *Humulus* type pollen curves, since *Humulus lupulus* is considered to grow as a liane in *Alnus* forests under natural conditions (Fries, 1958). On the other hand, the zone is too short for any significant climatic change to take place. The other possibility is the abandoning of activities centred on the lake shore in favour of the alvars (agriculture), as the curves for the *Cerealia* rise at the end of the sub-zone.

Zone 9. – A well-defined opening of the forest cover with a gradual increase in human impact (after Berglund and Ralska-Jasiwczowa, 1986) is in progress.

Zone 10. – Non-arboreal species are abundant, most probably because of the dry period in the recent lake history, during which the lake basin was covered with terrestrial vegetation. Pollen of the *Helianthus* type is typical of this zone, including *Bidens*, which
is today widely represented in the low lying areas around the lake. High fungal hyphae values in this zone in particular, but also in the previous one, are due to penetration by plant roots and better oxygen access during the dry period. This is supported by the accompanying higher values for the degree of destruction. A sudden increase in charcoal fragments, especially particles > 40 µm, is thought to be due to the tradition of burning old grass in the spring, in this case in situ, i.e. the lake bottom itself served as a grassland. A single find of a *Hippophae* pollen grain in the upper part of this zone may be connected with the open-pit mines, as *Hippophae* grows nowadays on the virgin soils of the waste dumps from which the water is pumped into the lake.

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REFERENCES


ANDERSSON, G., 1895, Om några växtfossil från Gotland, in *Geologiska Föreningen Stockholms Förhandlingar*, 17, p. 35-52.


