# Early Neolithic human impact on the vegetation in a wetland environment in the Noordoostpolder, central Netherlands

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## Abstract

The Noordoostpolder is an archaeologically rich area in the central Netherlands. A sediment profile, situated on a dune slope, was sampled near a Neolithic settlement site on the former island of Schokland. To reconstruct the local and regional vegetation around a Neolithic settlement, pollen, non-pollen palynomorphs and macrofossils were analyzed. The lowest part of the profile represents mid-Holocene peat growth on Pleistocene cover sand. Based on anthropogenic indicators like Cerealia and apophytes, the impact of early Neolithic people living in the nearby settlement was prominent. In addition to the pollen record, the spores of coprophilous fungi appeared to be valuable palaeoenvironmental indicators for human impact. The sampled sequence shows the effects of a rising water table related to sea level rise. The results support Cappers and Raemaekers' (2008) model of small-scale wetland farming in the early Neolithic.

## 1 Introduction

The Flevoland polders – the Noordoostpolder, Oostelijk (Eastern) Flevoland, and Zuidelijk (Southern) Flevoland – in the central Netherlands contain a rich assemblage of archaeological remains. The region of the former river valleys of IJssel and Vecht in the Flevoland polders was inhabited by hunter-gatherers and early farming communities throughout the Final Palaeolithic, Mesolithic and Neolithic (Peeters 2007). During the earlier part of the Holocene, Mesolithic people used an environment that changed profoundly as a result of climate change and subsequent relative sea-level rise. Dry dune tops were favourable dwelling places, but human use of the landscape was not restricted to high and dry places (Peeters 2007). For many years it was generally believed that hunter-gatherers had little or no measurable influence on the environment and the vegetation in particular (Waterbolk 1985). There is, however, mounting evidence for deliberate burning of vegetation zones (e.g. Bell 2007; Bos & Urz 2003; Bos *et al.* 2005), which may have had an impact on the (local) structure and composition of the vegetation (Zvelebil 1994), animal communities (Dods 1998, 2002) and hydrology.

Based on radiocarbon dates, Mesolithic hunter-gatherer activity in the former IJssel-Vecht valleys occurred in the Early and Middle Atlantic period (c. 7000-5000 cal BC). The evidence comes from river dune localities (compare Price 1981; Whallon & Price 1976; Groenewoudt *et al.* 2001; Bos *et al.*, 2005) and therefore may not be representative for Mesolithic landscape use on a broader scale (Peeters 2007). From the Late Atlantic/Early Neolithic onwards, the area was inhabited by people of the Swifterbant Culture (c. 5000-3600 cal BC). In the 1970s a number of important sites were discovered on aeolian river dunes and natural levees in the palaeo-stream valleys of the Overijsselse Vecht and Gelderse IJssel (de Roever 1976; Price 1981; Van der Waals 1977; Whallon & Price 1976) (fig. 1). Available evidence suggests that the earlier Swifterbant people were hunter-gatherers who used pottery, while cattle herding only played a minor role (Peeters 2007; Raemaekers 1999).

*Figure 1 Location of the sites mentioned in the text. (1) Schokkerhaven-E170, (2) Schokland-P14, (3) Urk-E4, (4) Swifterbant cluster of sites, (5) Hoge Vaart-A27.*

Ever since the discovery and (partial) excavation of some of the sites, the Swifterbant Culture has played an important role in the debate on the spread of agriculture and the neolithization process in the Dutch Delta (de Roever 2004; Hogestijn 1990; Raemaekers 1999). In particular the discovery of charred cereal grains (*Hordeum vulgare*, *Triticum dicoccon*) at Swifterbant-S3 triggered the discussion on the (im)possibilities of cereal cultivation in tidal wetland environments in the early Neolithic (Van Zeist & Palfenier-Vegter 1981). Subsequent discovery of charred cereal grains at other localities, such as Schokkerhaven-P14 (Gehasse 1995) and Urk-E4 (Peters & Peeters 2001) made it clear that the finds at Swifterbant-S3 were not anomalous. Several radiocarbon dates indicated an age between c. 4300-4100 cal BC. Large scale excavations at the Swifterbant Culture locality of Hoge Vaart-A27 with dates ranging between c. 4900 and 4300 cal BC did not, however, record any indications for cereal cultivation (Brinkkemper *et al.* 1999).

Renewed investigations at the natural levee sites near Swifterbant provided important new insights into the 'problem' of cereal cultivation in wetland environments. Charred cereal grains have been found in several localities (Cappers & Raemaekers 2008). But more importantly, direct evidence for local cultivation was discovered at the site of Swifterbant-S4 in the form of a field with clearly recognizable hoe marks. Multi-disciplinary analysis of micromorphological thin-sections, diatoms and phytoliths underpin the interpretation of these features as the product of anthropogenic reworking of the soil and the presence of cereals (Huisman *et al.* 2009). Based on present evidence, it seems that the scale of cereal cultivation (combined with husbandry) would have been rather restricted and it is more appropriate to speak of horitculture, rather than agriculture (cf. Cappers & Raemaekers 2008).

The study on the geographical occurrence, timing, nature, and environmental setting of cereal cultivation remains important to deepen insights into Swifterbant subsistence strategies and to develop further models on the roles played by early cultivation activities cultural change. We contribute to this with the present study, based on palaeoecological data reflecting human interference at site Schokkerhaven-E170. The site is one of the few known places where the Swifterbant Culture occupation is succeeded by the Funnel Beaker Culture. As yet, very little is known about this period.

## 2 Schokkerhaven-E170: geological context and stratigraphy

The geomorphology of the Central Netherlands changed considerably over the course of the Saalian through to the Weichselian (de Mulder *et al.* 2003). The Saalian glaciation stands at the basis of the formation of ice-pushed ridges which partly surround the Flevoland polders and deep basins in the northern half of the Netherlands. One such basin is present in the Flevoland area. The basins became filled with fluvioglacial, marine and organic terrestrial sediments at the end of the Saalian and throughout the Eemian interglacial, while the Weichselian cold stage was characterized by the deposition of aeolian cover sands over vast areas.

During the early Holocene the geomorphology of the landscape changed under the influence of processes induced by sea-level rise and fluvial dynamics. The Noordoostpolder area was increasingly influenced by rising (ground) water tables, in particular during the Middle and Late Atlantic (Gotjé 1993; Van de Plassche *et al.* 2005). The growth of basal peat gradually followed the upsloping Pleistocene surface from west to east. At the same time, the area was increasingly influenced by changes in the tidal patterns due to the encroaching shoreline. However, tidal influence halted when the coastal barrier along the western coast closed during the Subboreal, resulting in the formation of an extensive freshwater lake (*Almere*) in the area and erosion of peat deposits due to surges in Subboreal and Subatlantic times. The re-opening of the northern coastal barrier in the Subatlantic resulted in the formation of an inland sea (*Zuiderzee*) and almost complete inundation of the area. Only some small islands formed on outcrops of glacial till remained dry land, until systematic land reclamation (between 1942 and 1968) subsequent to the construction of a dam (*Afsluitdijk*) in 1932 altered the entire nature of the area.

The site of Schokkerhaven-E170 (Dutch coordinates 179.811/514.625) is located southwest of the former island of Schokland (the base of which is formed by an outcrop of glacial till), on a west-east oriented aeolian river dune that stretches over at least 600 m and is some 200 m wide. The dune is flanked by a gully in the south. The highest parts of the dune, above roughly 4 m below NAP,[1] were eroded due to natural processes and anthropogenic activities. Below this level the stratigraphy is undisturbed and represents the natural accumulation of peat with clastic sediment and sandy and anthropogenic components. The local stratigraphic sequence on the slopes of the river dune at Schokkerhaven-E170 is up to several meters thick. The upper part consists of marine Zuiderzee deposits of which the top is ploughed. The stratigraphic sequence in general terms, as depicted in Figure 2 (from top to bottom), consists of the following layers:

1. locally undisturbed lacustrine Almere deposits (silty and humic clay) with locally reworked sand at the bottom, originating from the top of the dune
2. brook peat deposits (the upper part is desiccated due to the presently low water table)
3. detritus/gyttja with some clay
4. humic sand (A-horizon)
5. river dune sand (C-horizon)

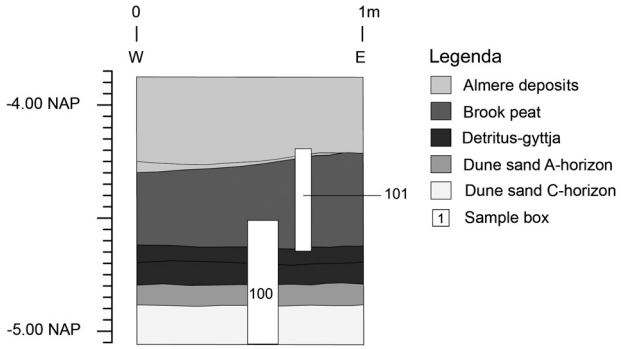


*Figure 2 Profile of the trench at Schokkerhaven-E170 and position of the sample boxes.*

The thickness of layers 3 and 4 varies strongly and this is related to the surface level of the river dune sand. The timing of the start of peat growth along the dune slope at Schokkerhaven was related to the elevation of the sandy substrate and local (ground) water level. Peat layers formed a natural archive of the local and regional vegetation by embedding microfossils (among which pollen and fungal spores), seeds and other macrofossils.

At the site, archaeological materials were found in the upper layer of the sand dune and on the slopes in the layers 3, 4 and 5. The great majority of finds consists of knapped flint and pottery fragments, the latter are principally assigned to the late Swifterbant Culture (Hogestijn 1990; Raemaekers 1999, 2005). Three radiocarbon dates on hazelnut shells, charcoal and the food crust from a pottery sherd (collected *in situ* from layer 4 on the dune's southern slope) produced results between c. 4000 and 3700 cal BC (Lanting & Van der Plicht 2002) and these dates are synchronous with the late Swifterbant Culture. Furthermore, three wooden posts (possibly belonging to a palisade) sampled from layer 3 produced dates between c. 3500 and 3100 cal BC (Lanting & Van der Plicht 2002). These dates correspond to the Funnel Beaker Culture, which succeeded the Swifterbant Culture in the region. In addition to remains of the Swifterbant and Funnel Beaker cultures, there is also evidence for Mesolithic flint artifacts and Neolithic pottery remains.

## 3 Methods

Two undisturbed sequences of peat and sandy subsoil were sampled in metal boxes (50 x 15 x 10 cm and 50 x 5 x 5 cm respectively). A 1 x 1 m wide sampling trench was dug for this purpose at the southern slope of the sand dune, subsequent to the stratigraphic mapping by means of coring. The sample boxes were packed in plastic bags after their extraction in order to prevent contamination and desiccation. Detailed sampling for microfossil and macrofossil analysis was conducted in the laboratory. The sub-samples for macro- and microfossils were collected from the same depths. Microfossil samples were 1cc, macrofossil samples were ~ 7cc (1 cm thick). Thirteen sub-samples were taken at 4 cm intervals from the upper box and twelve sub-samples were taken from the lower box. In the middle part of this box, in an area labeled as Zone II, sample distance was 2 cm. The depth of the sub-samples given in Figure 3 is in cm below NAP.

The sampling location has some implications for the interpretation of the pollen and macrofossil records. Since the site is located on a slope, the sample contains both localized vegetation and also remains from upslope and down slope. The conditions on top of the dune would have been dry, while the sampling site had already become influenced by the rising water table. The local vegetation change along the slope would thus include the effects of the rising water table.

## *Microfossil analysis*

For the study of microfossils, twenty-five sub-samples from the 85 cm high profile were prepared according to Faegri & Iversen (1989). Pollen, fern spores, fungal spores and other palynomorphs were recorded with a magnification of 400x (and 1000x when necessary). Pollen identification was performed with help of an extensive reference collection and with the keys and illustrations by Moore *et al.* (1991) and Beug (2004).

During the initial analysis no distinction was made within the Cerealia-pollen type (measuring more than 38 μm; diameter of annulus more than 8 μm), because relatively large pollen grains of some wild grass species (e.g. *Glyceria* and *Bromus*) are difficult to distinguish from pollen of Cerealia (Beug 2004). Cereals and wild grasses however, grow in different habitats. *Glyceria* usually grows in moist to wet habitats, while cereals are usually cultivated on dryer soils. Therefore, at a later stage, all large Poaceae pollen grains were measured again (total diameter; size of pore and annulus) and in addition to the size, the ratio between pore diameter and annulus width was also measured because relatively large pores are also an indication for wild grass pollen (Tweddle *et al.* 2005). If the pore diameter was twice the width of the annulus, the pollen most likely belonged to *Glyceria*. Within the Cerealia-type both 'real' Cerealia (diameter more than 38 μm and a pore smaller than two times the annulus width) and wild grasses with relatively large pollen grains could be distinguished (fig. 4). The ratio between cereal-pollen and *Glyceria*-type pollen within the Cerealia-type was ca. 50:50.

The plan was to count a pollen sum (Σ-pollen, used for percentage calculations) of 400 pollen grains, excluding grasses and local taxa such as aquatics and wetland species. In most of the samples this number was reached (fig. 3), but microfossils in the upper and lower parts of the sampled profile were badly preserved, making counting and identification rather difficult. In those samples a pollen sum of 400 was not achieved; 250 grains of arboreal pollen was then set as a minimum. The groups and taxa included in the pollen sum are listed in table 1. The pollen taxa not included in the pollen sum and also the non-pollen palynomorphs are expressed as percentages based on the pollen sum.

| Trees | Shrubs | Herbaceous taxa |
|---|---|---|
| *Alnus* | Ericales | *Artemisia* |
| *Betula* | *Myrica* | Asteraceae liguliflorae |
| *Corylus* | *Rhamnus cathartica* | Asteraceae tubiliflorae |
| *Fagus* | *Rhamnus frangula* | Brassicaceae |
| *Fraxinus* | *Viburnum* | Campanulaceae |
| *Picea* | | Caryophyllaceae |
| *Pinus* | | Chenopodiaceae |
| *Quercus* | | *Circaea* |
| *Salix* | | *Fallopia* |
| *Tilia* | | *Melampyrum* |
| *Ulmus* | | *Plantago lanceolata* |
| | | *Plantago major/media* |
| | | *Polygonum persicaria-type* |
| | | *Rumex acetosella*-type |
| | | *Succisa pratensis* |
| | | *Urtica* |

*Table 1 Taxa included in the pollen sum*

## *Analysis of macroremains*

Samples for the analysis of microfossils and macroremains were taken at corresponding depths; volumes of c. 7 cc were kept cool and sealed until the analysis of macrofossils started. Preparation of samples was done according to Mauquoy & Van Geel (2007). Samples were gently boiled in 5% KOH solution and then rinsed in a metal sieve with a mesh size of 160 µm. Residues were flushed into glass beakers with demineralised water. The residue was poured into a petri dish and placed under a binocular microscope. Volume percentages of charcoal and sand were estimated; the remaining part was categorized as organic debris. The species composition of the organic debris could not be identified in many of the samples, but in general the material consisted of a combination of leaf and root material. Fruits, seeds and other objects that could be identified were put in china cups with glycerin. A reference collection for fruits and seeds was used in addition to existing literature (Birks 2007; Körber-Grohne 1964; Mauquoy & Van Geel 2007). For practical reasons all fruits and seeds are referred to as seeds, despite the fact that this might not always be the correct botanical name. Samples that were selected for $^{14}C$ dating were stored in millipore water. The record of macrofossils, shown as bars in Figure 3, represents counted numbers per sample of c. 7 cc.

## *Combined micro- and macrofossil diagram*

In the diagram (fig. 3), a combination of pollen percentages and macrofossils (numbers) is given. Macrofossils are shown by bars and pollen percentages by lines connecting percentage values. Calculations and visualizations were made using the Tilia software (Grimm 1990). If pollen or seeds were very rare, finds are visualized by a plus (+) symbol. Pollen types with low percentages but with an indicative value were exaggerated five times. This is indicated by an

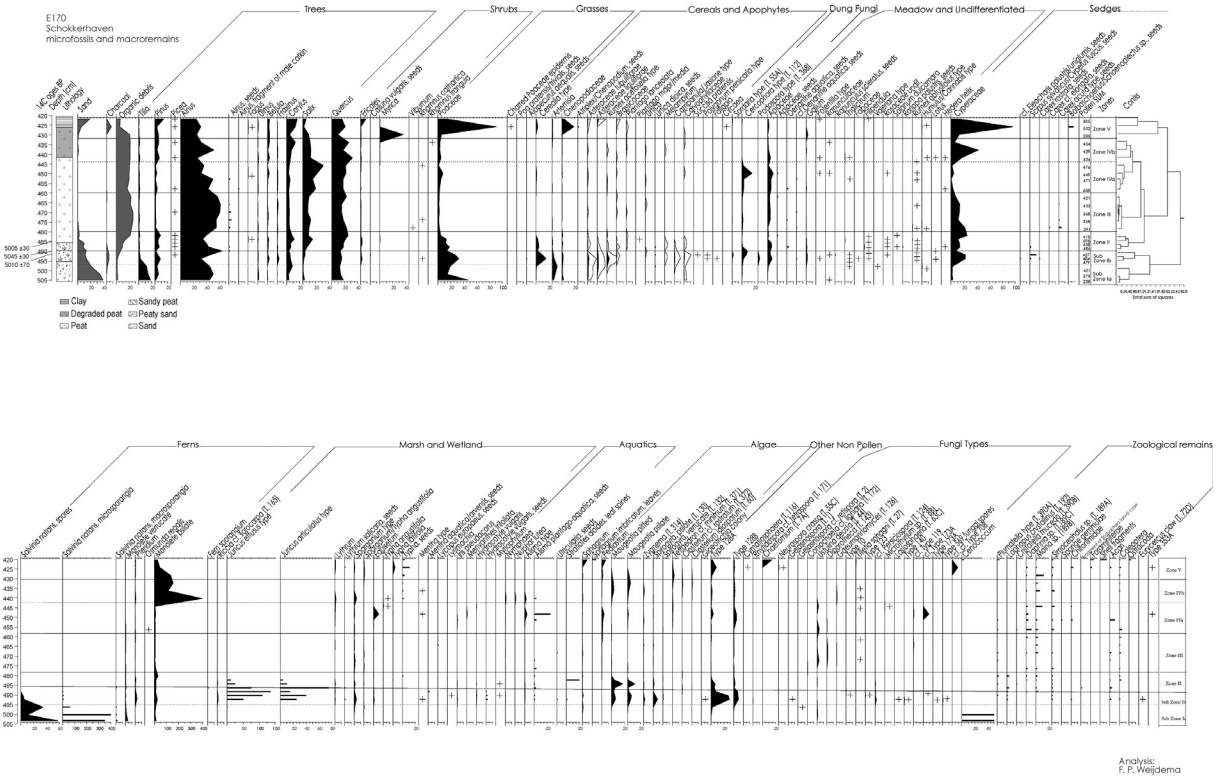


*Figure 3 Microfossil and macroremains diagram from site Schokkerhaven-E170.*

open curve on top of a solid curve. Zonation of the diagram is derived from the CONISS calculations (Grimm 1987). These calculations are based on the taxa in the pollen sum only. The CONISS figure is displayed at the end of the upper half of the diagram.

### *Dating*

Three samples from the profile, at 494, 492 and 486 cm below NAP, were selected for radiocarbon dating. A sample containing seeds from non-aquatic plants was chosen to prevent contamination with younger root material and to avoid reservoir effects. Due to lack of material only one of the three samples (494 cm below NAP) was composed of seeds (total 0,596 mg dry weight). The other two were bulk peat samples. Results are shown in table 2.

| cm -NAP | 14C BP | Laboratory number | material | 95,4% (2σ) age intervals after calibration |
|---|---|---|---|---|
| 486 | 5005 ± 30 | GrA-39737 | bulk | 3812 - 3703 cal BC |
| | | | | 3939 - 3859 cal BC |
| 492 | 5045 ± 30 | GrA-39696 | bulk | 3952 - 3768 cal BC |
| 494 | 5010 ± 70 | GrA-39695 | seeds | 3685 - 3660 cal BC |
| | | | | 3954 - 3690 cal BC |

*Table 2 Radiocarbon dates of three samples with range in calendar years BP derived from Calib 5.0 (Stuiver & Reimer 1993) using the INTCAL 08 calibration curve.*

## 4 Results

The vegetation development in the lower part of the sampled profile shows fast transitions related to the start of peat growth. Apart from the natural factor of a rising water table, the vegetation succession at the sampling site may also have been affected by sedimentation of sand as a consequence of erosion at the nearby upslope human settlement site. Eutrophication related to the settlement may have also influenced the local species composition.

### Zone I (505 – 487 cm below NAP)

In this sandy soil part of the profile, pollen was badly preserved. The zone was subdivided in two subzones, this division is mainly based on the large differences in the representation of *Salvinia* spores and Cyperaceae pollen. Pollen of trees, mainly *Alnus* and *Quercus*, is dominant. Pollen of *Tilia* is relatively abundant in the lowest sample but starts to decline afterwards. Pollen of *Salix*, *Corylus*, *Ulmus* and *Betula* occurs regularly.

### Subzone Ia (505 – 497 cm below NAP)

This subzone represents the sandy subsoil, which originally (before the rise of the water table) may have represented a dry soil at the sampling site. The relatively high *Tilia* values indicate a local forest dominated by lime, with Polypodiaceae (monolete verrucate spores) in the understorey. In the wetter parts of the landscape *Alnus* and *Quercus* were dominant. Several aquatic taxa that characterize subzone Ib are still absent in Ia. Sclerotia of the soil fungus *Cenococcum* occur. Cyperaceous pollen still shows low values while *Juncus* seeds are absent. The high representation of *Salvinia* - a small floating fern (fig. 4) - may indicate the start of wet conditions with some bioturbation bringing microspores, microsporangia and macrosporangia downward into the soil. Alternatively the sandy deposit of subzone Ia may be the result of uphill erosion (hu-

man interference; see below) and fast sedimentation in wet conditions at the sampling site where *Salvinia* was already growing as a pioneer, while the sclerotia of the soil fungus *Cenococcum* may have arrived together with the eroded sand. Apophytic taxa (*sensu* Behre 1981, for an explanation see discussion below), *Artemisia*, other Asteraceae and Caryophyllaceae are present. These are indicative of plant communities on open ground and may be considered as indicators for (Mesolithic) human presence, but Cerealia-type pollen is still absent.

### Subzone Ib (497 – 489 cm below NAP)

Two radiocarbon dates are present from the basal part of this zone, i.e., the 494 cm below NAP-level was dated to 5010 ± 70 BP (ca. 3950 – 3650 cal BC), while the 492cm below NAP-level was dated 5045 ± 30 BP (ca. 3950 – 3770 cal BC).

In this part of the sequence, the sediment becomes very organic. *Salvinia* is still present but shows a decline, while spores of Zygnemataceae (*Mougeotia*; *Zygnema*-type and some *Spirogyra*) indicate shallow stagnant water, at least during spring time (Van Geel 1976; Van Geel & Grenfell 1996). The algal spore Types 128A and 128B (Van Geel *et al.* 1989) and Bryozoa (*Plumatella*-type, *Lophopus crystallinus*) and Cladocera (*Daphnia*, *Moina*, *Simocephalus*; Van Geel *et al.* 1983) indicate wet and eutrophic local conditions. Other aquatic taxa are *Utricularia* and *Stratiotes aloides*.

The local vegetation was dominated by *Juncus*. Both *J. effusus*-type and *J.-articulatus* type occur with *Lythrum salicaria*, *Alisma plantago-aquatica* and *Mentha aquatica/arvensis*. *Hydrocotyle vulgaris* represents a transitional phase with alternating wet and dry conditions. The *Alnus* percentages decreased substantially and at the same time the first peak in Cerealia-type pollen occurs. *Rumex acetosella*-type shows a maximum, most probably linked to agriculture. Asteraceae generally increase, except *Artemisia;* other apophytic taxa (e.g., *Melampyrum, Campanula/Jasione* type, Brassicaceae and Caryophyllaceae), are at their highest level in this zone. Furthermore, taxa such as *Polygonum persicaria* type, *Urtica dioica* type and *Fallopia* are also present. In general, the botanical diversity is high: *Potentilla*-type, Ranunculacae, Fabaceae, Rosaceae and *Lotus* Spores of coprophilous fungi, such as *Cercophora*-type, *Sordaria*-type and *Podospora*-type (Van Geel *et al.* 2003; Van Geel & Aptroot 2006) show high values. *Pteridium aquilinum* and *Riccia cf. sorocarpa* (Hepaticae) spores are found regularly. *Pteridium* is a pioneer benefiting from new open places in a forest, especially after forest fires. It may be linked to human impact (Iversen 1973). *Riccia* indicates temporary water table levels below the soil surface. It may also have been linked to human habitation as it sporulates on moist arable land (Koelbloed & Kroeze 1965; Van Geel *et al.* 1983).

### Zone II (489 - 480 cm below NAP)

The peat at 486 cm below NAP was dated 5005± 30 BP (ca. 3700 - 3940 cal BC).

The recorded leaf spines of *Stratiotes aloides* indicate the presence of open water. *Alisma plantago-aquatica* and *Oenanthe aquatica* point to temporarily wet conditions, however, *Oenanthe* can also grow on drier substrates. *Sparganium* and *Typha* are typical bank species. Both Poaceae and Cerealia-type show high percentages at the first part of the zone and a decline later on. *Quercus* is abundant, and *Salix*, *Corylus* and *Pinus* pollen is present in low amounts. *Alnus* shows varying levels apart from one higher peak at the base of this zone. Ericales show two small peaks. Apophytes are still relatively abundant. Asteraceae - both tubuliflorae and liguliflorae - are present. *Rumex acetosella*-type and *Plantago lanceolata* are present in low percentages. The latter may suggest grass land. Other apophytes also occur in low numbers, e.g., *Urtica, Melampyrum* and *Campanula/Jasione* type. Spores of coprophilous fungi, such as *Cercophora*-type (Van Geel *et al.* 2003; Van Geel & Aptroot 2006) are present. *Juncus* species, Zygnemataceae (*Mougeotia*, *Spir-*

*ogyra*) and Type 128A (algal spores) show a decline and disappear at the end of the zone. The *Salix* pollen curve shows an increase, indicating the local development of a willow carr.

### Zone III (480 – 460 cm below NAP)

The accumulation of peat continued under eutrophic conditions, with local taxa such as *Alnus, Salix*, *Oenanthe aquatica, Lycopus europaeus,* Cyperaceae and Cladocera. The *Pinus* values show a minimum in this zone. *Corylus* values also decrease but not as much as *Pinus*. Grasses are almost absent in the entire zone, as are other herbaceous taxa. Pollen grains of shrubs like *Viburnum opulus* and *Rhamnus cathartica* were observed as single finds. Sedges are well represented by pollen as well as by seeds. The spores of the parasitic fungus *Kretschmaria deusta* (formerly *Ustulina deusta*) occur. *Kretschmaria* thrives on different tree species (Van Geel & Andersen 1988).

### Zone IV (460 – 432 cm below NAP)

Percentages of tree species are high, in particular high percentages of *Salix* pollen are recorded. *Alnus* is not as abundant as in the previous zone. Cyperaceae and monolete psilate fern spores (probably *Thelypteris palustris*) show low frequencies in the lower part, but show a maximum in the upper part of the zone. A peak of *Cercophora*-type occurs in the lower part of this zone. Two sub-zones were distinguished.

### Subzone IVa (460 – 444 cm below NAP)

*Salix* pollen percentages show a strong increase to maximal values, while *Alnus* declines, probably indicating a rise of local water tables. A local occurrence of wet *Salix* forest seems likely. Such a rise is also suggested by the presence of *Alisma* (pollen and seeds) and relatively high values of the algae *Pediastrum* and Types 128A and 128B. A small peak of *Equisetum* indicates the temporary local presence of horsetail. Three types of waterflees (Cladocera) were recorded: *Moina*, *Simocephalus* and *Daphnia*. The presence of marsh and wetland plants like *Lythrum salicaria*, *Alisma plantago-aquatica*, *Equisetum*, *Iris pseudacorus* and *Menyanthes trifoliata* point to marshy and eutrophic to mesotrophic conditions.

*Quercus* shows relatively high percentages. Poaceae are still at a very low level. Cyperaceae pollen is almost absent. Small peaks of Brassicaceae and *Rumex acetosella*-type occur and some Cerealia-type pollen was found. High percentages of spores of coprophilous fungi (*Cercophora*-type) are present. One spore of *Osmunda* was recorded, but ferns were not present in the local vegetation. Apiaceae are relatively abundant in this subzone.

### Subzone IVb (444 – 432 cm below NAP)

In the lower part of the subzone pollen of *Nuphar* and *Nymphaea* occur indicating the presence of pools with open water. *Mougeotia* spores also indicate shallow open water, at least during spring time. Monolete fern spore values show a sudden increase, together with the Cyperaceae pollen curve. The *Alnus* pollen curve shows a high peak in the middle of the zone, but no macroremains were found. *Salix* shows relatively high percentages, but considerably lower than in the previous zone and suggests that the local willow carr has become more open. Pollen of *Alisma plantago- aquatica* and *Typha* seeds occurs regularly. *Sphagnum* spores together with some spores of its fungal parasite *Tilletia sphagni* may indicate the nearby occurrence of *Sphagnum* and a decline in the availability of nutrients. Apophytes are present in very low percentages and spores of coprophilous fungi are absent. *Pinus* percentages are somewhat higher in this zone and some *Picea* pollen was recorded.

## Zone V (432 – 420 cm below NAP)

The upper sample of the profile represents the base of a clay layer. Shell fragments and Foraminiferae are present and Chenopodiaceae pollen shows a sudden rise, indicating that flooding and deposition of the sediment occurred under brackish or marine conditions. The sediment in this zone was formed by material of different origin. Several taxa appear, indicating a mixed composition of the increasingly sandy, and in the upper part certainly reworked, sediment. A combination of pollen of cereals and apophytes is present, but in low percentages and without spores of coprophilous fungi. A sudden peak of *Myrica* indicates the local occurrence of this shrub during a phase when peat growth ended. The *Myrica* peak is followed by a sudden sharp increase in Poaceae pollen. A hiatus in the middle part of zone V as a consequence of oxidized or eroded peat is probable. In this zone a non-pollen palynomorph resembling Type 708 (Bakker & Van Smeerdijk 1982) was recognized. The presence of *Chaetomium* ascospores (Type 7A; Van Geel & Aptroot 2006) indicates the enhanced breakdown of cellulose in plant debris. In the upper sample Ericales pollen and *Sphagnum* spores show an increase, while leaves of *S. imbricatum* were recorded. These remains probably represent reworked raised bog peat that was eroded by the sea in the area between the present provinces of Noord-Holland and Friesland (Zagwijn 1986) during the Subatlantic period and finally deposited with the marine sediments.

*Figure 4 (1) Cereal-type pollen with thick annulus. (2)* Glyceria*-type pollen with relatively large pore and narrow annulus.*
*(3 – 6) Remains of Salvinia natans: (3) and (4) Microsporangium with microspores. (5) Macrospore. (6) Microspore.*

# 5 Discussion

## *Salvia natans*

A recent overview of *Salvinia* finds from archaeobotanical literature by Out (2010), which also includes the finds in the present study, shows that Schokkerhaven is the most northern location of mid-Holocene *Salvinia* finds. It is the only location outside the Rhine/Meuse river area. Formerly, finds of *Salvinia* were dated to the Atlantic (early-Neolithic) mainly based on Zandstra (1966). The overview by Out provides more finds that are dated in the transition from Atlantic to Sub-Boreal and shows the occurrence of *Salvinia* during the Sub-Boreal (late-Neolithic) period. This fits with the occurrence of an other thermophilous aquatic species, namely *Trapa natans* elsewhere in the Netherlands. *Trapa* was frequently recorded in the early Subboreal (archaeobotanical database RADAR; Van Haaster & Brinkkemper 1995; Behre 1970).

## *Reconstruction of vegetation development*

The presence of *Alnus*, *Ulmus* and *Tilia* pollen in the sandy soil points to an Atlantic (approximately late Mesolithic) age (Van Geel *et al.* 1981) of the base of the studied profile. Before peat growth started (Zone Ia), the presence of spores and macrosporangia of *Salvinia* indicate local aquatic conditions. The presence of *Salvinia* is followed by *Riccia* (Zone Ib), probably indicating alternating wet and dry conditions. On the higher parts of the dune a *Tilia* forest was present with some open areas where *Artemisia*, Asteraceae and Brassicaceae were growing. As a result of a rise in the groundwater level, the *Tilia* forest disappeared and a wetland forest with *Alnus* and other marsh- and wetland species could develop.

The variety of herbaceous taxa increased when the first cereal cultivation started (Zone Ib). The landscape became more open and richer in nutrients, favouring plants such as *Solanum dulcamara*, *Valeriana* and *Succisa* (Zone Ib and Zone II).

Later, the *Alnus* forest declined and a *Salix* carr could develop in most wet areas. Furthermore, the crops and the species associated with meadows declined when conditions became wetter (Zone III). *Lythrum*, *Alisma*, *Mentha* and *Typha* were found in the nutrient-rich marshes (Zone IVa). Open water was present in the lower parts down slope, but whether there was permanent open water or seasonal inundations is not clear.

On the dry parts of the dune *Quercus* trees and meadow plants remained present. When *Salix* declined, many other trees became less important (Zone IVb). Poaceae, filices and Cyperaceae increased and the landscape became an open wetland. *Corylus* and *Pteridium* probably inhabited the slopes of the dunes and forest edges.

During the upper part of the studied profile *Myrica* shrubs developed in the area (Zone V). *Myrica* possibly was growing on the drained, decaying peat surface and there may have also been some cover of wet forest of *Alnus* and *Salix* Chenopodiaceae were linked to increased brackish or marine influence in the landscape.

## *Human impact*

Of special interest are the first attempts of prehistoric farming. The change from hunter-gatherers to organized farming communities is considered a key process in the history of humankind. This change would have been a long process of progress and setbacks. The first occurrence and location of agricultural practice in northwest Europe is disputed. Concluding whether an archeological site contains evidence for agriculture is rather subjective. Findings of

single pollen grains of the Cerealia-type have sometimes been used to reconstruct an entire Mesolithic agricultural society, an approach that was strongly criticized by Behre (2007). Herbaceous species linked to human occupation or disturbance (light; open soils) are indicated as apophytes (*sensu* Behre 1981). The natural habitat of apophytic species was in places disturbed by wind, fire or other natural causes (Wittig 2004). With an increasing amount of human settlements there were more disturbances, which was advantageous for the apophytes as they became associated with disturbance related to human settlements.

The palynological data from site Schokkerhaven-E170 show some close links between the occurrence of pollen of Cerealia-type and apophytes. This link could not be established in Zone Ia (Late Atlantic period). Both Asteraceae (both tubuliflorae and liguliflorae) and Caryophyllaceae occur in this zone but no cereals were found. In Zone Ib (radiocarbon dated: ca. 5000 BP; corresponding to ca. 3950 to 3700 cal BC) relatively high values of Cerealia, *Rumex acetosella*--type, Brassicaceae, *Melampyrum*, *Jasione*-type and Caryophyllaceae occur. Single finds of *Succisa*, *Polygonum persicaria* and *Fallopia* are also present in Zone Ib, while low amounts of pollen of *Urtica dioica* occur at the transition from Zones Ib to Zone II. Some apophytes follow the Cerealia-type curve more closely than others. The recorded plant taxa indicate the presence of various plant communities, *Urtica* points to nitrogen rich areas. Other taxa (*Fallopia*, *Polygonum persicaria*, Asteraceae, *Rumex acetosella*) are typical for arable fields while *Succisa* and *Plantago lanceolata* indicate meadows. The occurrence of Cerealia-type pollen alone cannot be taken as proof for agriculture (Behre 2007), but the presence of apophytes supports this interpretation.

The record of pollen of Cerealia at site Schokkerhaven-E170 is supported by a variety of other indicators for agriculture and apophytes, charcoal particles and the records of coprophilous fungi provide further support for human impact. The spores may have developed on human feces, but dung of wild and/or domesticated animals may have been the most important substrate for these fungi (Van Geel *et al.* 2003). With regard to the fungal evidence for grazing, it is not possible to distinguish between domesticated and wild animals.

In zones I and II the combined presence of cereals, apophytic species, coprophilous fungi and charcoal clearly indicate the presence of humans and agricultural activity. The three radiocarbon dates place the recorded human impact in the late-Swifterbant culture. The dates complement the radiocarbon dates obtained from charred hazelnut shells, charcoal and charred food remains from a pottery sherd (Lanting & Van der Plicht 2002) sampled at the site in the late 1980s by J.W.H. Hogestijn (see above). The Swifterbant culture in this region is succeeded by the Funnel-beaker culture. Possible indications for later human presence in the diagram are the peak of *Cercophora* spores in zone IVa and the small peak of Cerealia-type in zone V. Although the indications are not as strong, both could suggest local Funnel Beaker culture agricultural activity, corresponding to the radiocarbon dates obtained on some wooden posts (Lanting & Van der Plicht 2002), also sampled by Hogestijn.

## 6 Conclusions

The evidence for human impact in the surroundings of site Schokkerhaven-E170 is based on micro-fossils. The pollen record provides strong evidence for cereal cultivation, while indications for grazing were found in the presence of spores of coprophilous fungi (*Podospora*-type with *Cercophora*-type).

The $^{14}C$ dates corresponding to zones of agricultural activity suggest a date of about 3750 cal BC. This is somewhat later than the evidence from sites like Swifterbant-S3, Schokland-P14 and Urk-E4, with dates hovering between 4300 and 4000 BC. However, the results for Schokkerhaven-E170 provide evidence for another phase with agricultural activity in wetland environ-

ments in the later phase of the Swifterbant Culture. These data support Cappers and Raemaekers' (2008) suggestion that small-scale agriculture became an inherent aspect of wetland hunter-fisher-gatherer based economies. This applies to both the wetlands in the Flevoland area and other regions, for example along the coast in the Rhine-Meuse delta (Louwe Kooijmans 2006), and the northeastern Netherlands where pollen records show evidence for agricultural activity within a time frame that corresponds to the Swifterbant Culture (Bakker 2003).

The results of our research are surprisingly positive, considering the rather bad preservation of plant remains at this site. Our research establishes a link between human presence and their impact on the surrounding vegetation. The potential for further investigations and the possibility to expand our knowledge on earlier Neolithic environmental and cultural dynamics is subject to serious threats. The artificially lowered groundwater tables in the polder areas in Flevoland have damaged, and will further damage, the natural archive of the peat layers. To preserve this palaeoenvironmental archive for the future, groundwater tables should be kept relatively high, at least in areas of archaeological interest.

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## Note

1. Dutch Ordnance Datum

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