LÄNSSTYRELSEN
HALLANDS LÄN

Reconstructing Ecosystem dynamics, Fire History and long-term anthropogenic impact at Långhultamyren Nature Reserve, Halland, Southwest Sweden

Implications for future management

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Författare: Gina E. Hannon
Bild förstasida: Foto – Henrik Malm, bild över Långhultamyrens centrala delar mot väster från toppen på Långhulten, Långhultamyrens naturreservat i Hallands län.

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G. E. Hannon

Department of Geography and Planning, School of Environmental Sciences, University of Liverpool. UK. Roxby Building, Liverpool, L 69 7 ZT, U. K.

Sammanfattning

Våtmarkskomplexet Långhultamyren i Hallands län är ett 823 hektar stort naturreservat. Det ingår bland annat i EU:s nätverk för skyddad natur, Natura 2000, och våtmarkskonventionen Ramsar. Den här paleoekologiska undersökningen visar ett antal vegetationsförändringar som området genomgått från 7700 år tillbaka i tiden och fram till idag. Förändringarna kan förklaras av en kombination av mänsklig påverkan och klimatfaktorer över tid. Skogen som återkoloniserade våtmarkens omgivningar efter den senaste istiden blev variationsrik och innehöll många olika lövträd – ek, alm, lind, hassel, björk, avenbok, ask, lönn, asp, sälg, rönn och brakved. Träd (björk, sälg, tall, al) och risvegetation (ljung) växte i våtmarken fram till för cirka 2500 år sedan, men det har även innan det funnits öppna ytor: Perioder under tidig Holocen (cirka 7800–6000 år sedan), som i prover visar spår efter sedimentärt kol (bränder), resulterade senare i höga pollenhalter av gräs och sporer av örnbräken och stensöteväxter förknippade med öppen mark.

Undersökningen visar även att området har en lång historia av mänsklig påverkan. Under bronsåldern sammanfaller spår av bränder (kolfragment) med prov som innehåller *Sporormiella* svampsporer (lever i dynga från gräsätare) och en signifikant ökning av ljungpollen. Mänsklig påverkan ökar än mer under järnåldern, med stigande halter av *Sporormiella* sporer. Nu dyker även de första pollenkornen från sädesslag upp (råg och korn) och kornet återfinns i proverna fram till för ett par hundra år sedan. Bokens ankomst och fortsatta expansion verkar ha skett på bekostnad av *lind, ask, alm och ek* på myrens omgivande fastmark. *Al, björk, sälg och tall* växte både på fastmark och våtmark.

Buskvegetationen med pors som idag dominerar på myren, är en sentida företeelse och kan bara spåras ett par hundra år bakåt i tiden. Det är en dramatisk förändring som förstärks av insådd av gran och tall från omgivande skogsplantager. Utvecklingen beror troligen på avsaknad av brand, upphört bete och dränering av området. Barrträdens expansion på fastmarken sedan ett par hundra år bakåt i tiden har skett på bekostnad av boken. Dynamiken är ett resultat av en kombination av mänsklig aktivitet och naturlig spridning av gran i omgivningarna.

Abstract

Långhultamyren in the province of Halland in SW Sweden is a protected national nature reserve wetland complex of 823 hectares. It is included in Natura 2000 and the Ramsar Convention on Wetlands. Based on palaeoecological evidence, several phases of changes in the vegetation community are documented from c. 7700 years ago which are the outcome of a combination of anthropogenic use and a varying climate through time. Early forests surrounding the wetland were diverse and with a larger proportion of temperate trees – *Quercus, Ulmus, Tilia, Corylus, Betula, Carpinus, Fraxinus, Acer, Populus, Salix, Sorbus* and *Frangula*. Trees (*Betula, Salix, Pinus, Alnus*) and shrubs (*Calluna*) were growing on the wetland surface until at least 2500 years ago, but there have always been some open areas. Probable natural fires during the early Holocene from c. 7800 – 6000 years ago resulted in high values of Poaceae pollen and fern spores (including *Polypodium, Dryopteris* and *Pteridium*) during periods of sedimentary charcoal.

The long history of anthropogenic use is evidenced by renewed burning associated with people in the Bronze Age. This coincides with records of *Sporormiella* fungal spores, associated with the dung of animals along with a significant increase in pollen of *Calluna vulgaris*. There is more intense human use in the Iron Age with higher numbers of *Sporormiella* fungal spores recorded. The first cereal pollen grains (*Secale cereale* and *Hordeum*) are present and the latter remains in the record until the last few hundred years. The arrival and subsequent expansion of *Fagus* is most probably associated with the demise of *Tilia, Fraxinus, Ulmus* and *Quercus* in the surrounding upland areas. *Alnus*, *Betula*, *Salix* and *Pinus* were both growing in the uplands and on the mire.

The shrub that today dominates the mire (*Myrica gale*) is recent, and only stretches back some hundreds of years. It is a drastic change to the mire surface, particularly with the incursion of *Picea* and *Pinus* seedlings from neighbouring plantation forests. This recent development is likely a result of the lack of fire, the virtual abandonment of grazing, together with drainage. The expansion of coniferous trees in the last few hundred years on the higher areas has occurred at the expense of *Fagus.* These dynamics are a result of a combination of human activities and the natural spreading of *Picea* into the region.

Table of contents

Introduction

Natural forces such as climate change, together with human activity including commercial forestry in recent centuries, have led to the reduction of diverse deciduous forests around an upland mire complex at Rånghultamyren in Halland, SW Sweden. Pollen, plant macrofossil, geochemical and charcoal analyses covering the almost the last 7.5 millennia have been used to reconstruct ecosystem dynamics, anthropogenic impact, fire history and past disturbance in this currently protected ecosystem complex.

An appreciation of present conditions, together with an understanding of the legacies from past disturbance, both natural and human-induced, allow us to propose management choices that might mitigate deleterious impacts of likely future climate change. Management decisions are often based on data from the historical period or from the present occurrence of key indicator and red-listed species. A longer, millennial perspective, can help identify legacies from former human impact that are hard to detect from present day communities (Brown et al, 2018, Halme et al, 2013).

Recent biotic homogenization and reduction in the mixed forest condition is likely to be linked to a loss of many species of insect, bryophyte and lichens that have been dependent in the past on *Quercus, Tilia, Ulmus, Populus, Alnus, Fraxinus, Fagus* and other deciduous hosts in southern Sweden. An understanding of vegetation dynamics over longer time scales can provide a history of variability of mosaic landscapes under variable climatic conditions. This is relevant for management decisions concerned with future climate change, invasive species and migrating fronts particularly where the keystone species (i.e. trees) have long generation times (Brown et al., 2018, Huntley et al, 2018, Clarke & Lynch, 2016, Halme et al., 2013).

The Länsstyrelsen in Halland has commissioned a report about the vegetation history of Rånghultamyren, as a background to inform management decisions to be taken for the protection of this rare and threatened habitat from invasion by woody shrubs on the wetland surface and loss of biodiversity. The aim is to provide an understanding of the long-term structure and composition of the mire complex and the surrounding highland areas, as this provides a framework for understanding future ecosystem response to climate change. Using a longer time perspective provides insight into ecological processes, both natural and anthropogenic, under different climatic regimes and avoids a static view of ecosystems.

Three main questions were addressed:

1. What are the ages of origin of the different components of the mire complex? These are to be dated using a combination of radiocarbon dating and the industrial Pb records.
2. What are the vegetational successions through time e.g., fen-bog transition? This will be established using pollen and plant macrofossil analyses.
3. What is the former extent of forest cover and composition? How open were parts of the mire complex in the past? This will be established using pollen and plant macrofossil analyses.

In addition, two further questions were also relevant.

4. What evidence is there for anthropogenic impact through time, for example, the use of grazing animals? This can be established, amongst other proxies, from the sedimentary record of coprophilous fungal spores (Lee et al, 2022). These spores occur in the dung of domestic livestock as well as wild herbivores.
5. What evidence is there for natural or anthropogenic burning in the past? This can be inferred from the sedimentary charcoal record.

Study setting

Långhultamyren is a protected bog complex of 823 hectares in the eastern part of Halmstads kommun and is part of an area included in Natura 2000. It is located to the east of Simlångsdalen between Halmstad on the coast and Ljungby inland (Figure 1) (GPS (WGS84): Lat. N 56° 43’ 31” Long. E 13° 13’ 8”) set aside in 1999 and expanded in 2022. Ownership is divided between Naturvårdsverket (The Swedish Environmental Protection Agency) and private individuals, with management by the Länsstyrelsen (Figure 2). During the 1700 and 1800s, large parts of the bog and surrounding higher ground were grazed and the area was burned regularly and kept open to improve grazing. When this management ceased at the beginning of the 1900s, parts of the wetland area were left to regenerate naturally and are closing over, while parts of the higher ground were planted with *Pinus* and *Picea*. The open woodlands on the higher areas are dominated by conifers with some deciduous trees and individual *Juniperus,* a legacy of the former grazing regime. The bog complex is dominated by *Myrica gale* at the margins, which with Ericaceous shrubs, *Salix, Betula, Pinus* and *Picea* are beginning to invade the bog surface. A decision was made to expand Långhultamyren reserve in 2022, to manage, protect and reconstruct valuable and threatened ecotypes including the open mires and heathland areas as well as woodland areas to protect their biodiversity.

Fieldwork

Sediment cores were collected in September 2021, from the deepest point of the wetland and another marginal site close to the upland area (Figures 3,4,5). A 7cm Russian corer (Jowsey, 1966) was used to recover sediment at the deepest point, at 1 metre intervals to a total of 451.5 cm deep, with an overlap of at least 5 cm for each drive. The sediment core at the edge was 70cm in length. The cores were wrapped in plastic film and placed in guttering to be safely transported away from the field site. They were then transferred to Liverpool University and stored in a cold room at approximately 4-5°C, until they were required for further analysis.

Figure 1. Långhultamyren Nature Reserve, South West Sweden

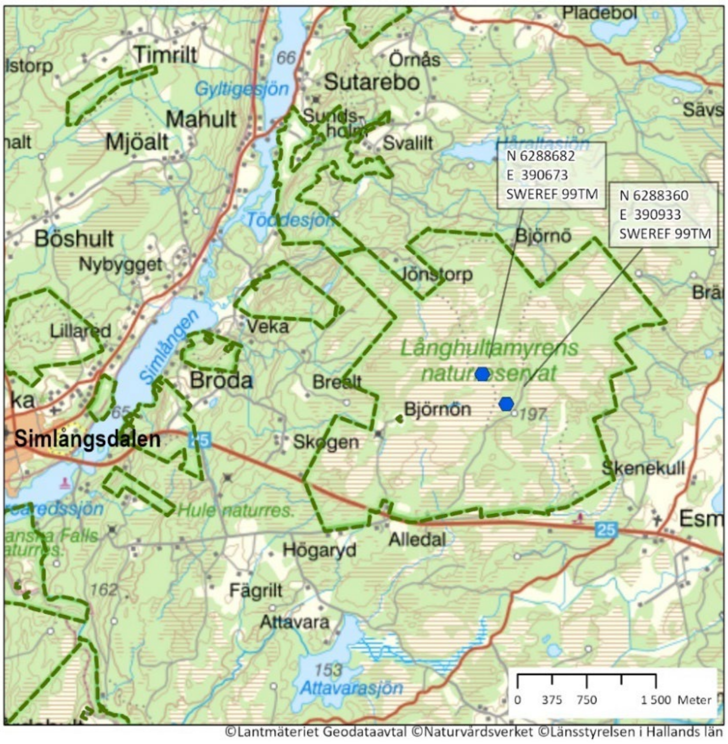

Figure 2. Study sites in Långhultamyren Nature Reserve. Main Core: N 6288682 O 390673 Marginal Core: N 6288360 O 390933 (Coordinate system SWEREF 99 TM)

Figure 3. Main coring site, Långhultamyren, September 2021.

Figure 4. Measuring the extension rod and marking depth for the second drive.

Figure 5. Extracting the sediment from the mire.

Palaeoecological methods

Pollen was subsampled at 5 cm intervals and prepared using standard methodology (Faegri and Iversen, 1989). Prior to subsampling, the sediment was scraped to remove any possible surface contamination and 1 cm samples were taken from a central point. After the pollen samples were prepared, glycerine was added to prevent the samples drying out. Sub-samples were mounted onto microscope slides with coverslips. A minimum of 300 upland terrestrial pollen grains per sample were counted, excluding fern spores or aquatics. Pollen and spores were identified using standard keys (Faegri and Iversen, 1989: Moore et al., 1994). Pollen percentage diagrams were drawn up using the computer programme TILIA, Version 2.0.41 (Grimm, 2015). The pollen sum included trees, shrubs, dwarf shrubs and terrestrial herbs. Local pollen producers were not included in the main pollen sum but presented on the diagrams as sub-sums added to the pollen sum so that their fluctuations would not interfere with the more regional signal from the upland areas surrounding the wetland complex. These local producers were *Myrica gale*, Polypodiaceae and *Sphagnum*. *Sporormiella* fungal spores (found in the dung of domestic livestock as well as wild herbivores (Lee et al, 2022)) were counted alongside the pollen counts and expressed as concentration.

Sievings collected during pollen preparation at each pollen level were used for plant macrofossil and charcoal analyses. The sievings were stored in double distilled water, washed into petri dishes, viewed under a binocular microscope and identified using Dr Gina Hannon's reference collection. The samples were then gently washed through a 250 µm sieve with double distilled water, and macrocharcoal units /cm^3 were counted and entered into the spreadsheet alongside the pollen depths and calibrated ages. Samples were stored in a cold room at approximately 4-5ºC until they were required for further analyses.

The charcoal residues were later bleached using 2% Sodium Hypochlorite solution to remove the colour from the vegetation and detritus within each sample and to enhance visibility of the charcoal without dissolving the particles (Schlachter and Horn, 2010). After 1 hour, the samples were then hand-rinsed and transferred back to the petri dish in distilled water. The charcoal fragments in each sample were visually counted, with black, brittle crystalline particles and with angular broken ends classified as charcoal (Swain, 1973, 1978). Each sample was then photographed with a digital camera Olympus Tough TG-840, and images were stored on a dedicated SD card.

The image analysis program Image J (Schneider et al., 2012) was used to analyse the photographs of the charcoal samples. Image J allows rapid digital quantification and descriptive analysis of the charcoal particles, using automatic recognition software. Image J produces a range of parameters, and the total area (mm^3) and count (number) of charcoal fragments in each sample were the main parameters used in this study. The Image J analysis was carried out by first creating a template to be used on all the images, this process was selected for efficiency, and to ensure the same treatment for every sample image. The template first de-specked the image, and then changed the image to grayscale (32-bit). The brightness of the image was set using the automatic function and a colour threshold was then set on the image tab. A general scale was set, by using a known distance in the photographs (petri dish diameter), and the scale was also re-adjusted for every image that was analysed to ensure accuracy (as there was some movement of the camera between batches of photographs to maximise image quality). The ‘Analyse particles’ function was used with a function to eliminate particles <0.01 mm^2, ensuring that tiny specks did not interfere with results. The analysis was performed using a colour threshold of 72. Each run would provide a separate text file with the results of the ‘analyse particles’ calculations in tab-delineated format.

The top sediment core was µXRF-scanned (Olympus Delta ED-XRF), on a wet sediment basis, using a Geotek MSCL-XZ core scanner to obtain the geochemistry and magnetic susceptibility (Schillereff et al., 2016). The industrial Pb record was used for dating purposes together with five samples for radiocarbon determination submitted to the AMS dating facility at Lund University for analysis (Table 1).

Results

Sedimentary Record

A total of 451.5 cm was retrieved from the main coring location at the deepest point in the bog complex (Figures 6,7,8,9,10,11). Layers of *Sphagnum* and fibrous and root material were followed by compacted layers of wood and charcoal and a base layer with mineral material. The sediment core at the edge was 70cm in length.

Top

Figure 6. Core 1: 0-100 cm.0-20, loose vegetative material including *Sphagnum* moss followed by fibrous peat, 20-100 cm.

Top

Figure 7. Core 2: 95-195 cm. Loose fibrous peat with *Sphagnum* and roots.

Top

Figure 8. Core 3:190-290 cm. Peat sediments with layers of *Sphagnum* and heathers.

Top

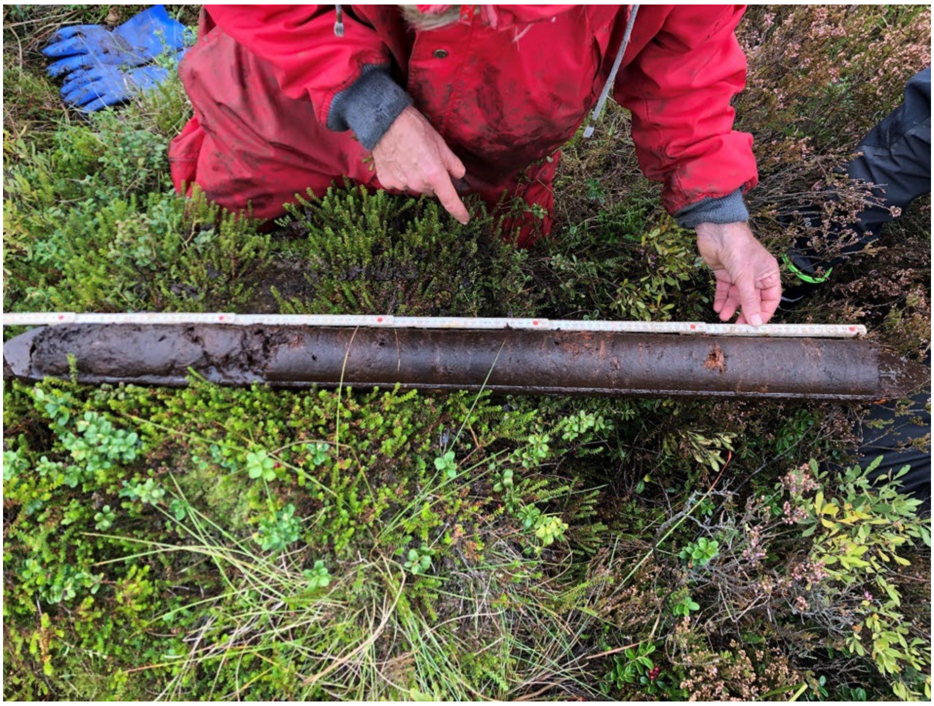

Figure 9. Core 4: 285-385 cm. Peaty gyttja with several wood layers and black charcoal bands.

Top

Figure 10. Core 5: 352-451.5 cm. Compact peaty gyttja with wood and charcoal layers, and base layer with mineral material.

Figure 11. Sedimentary Charcoal layers from the earliest sediments between 435 and at 451.5 cm (c. 6900-7500 years ago) and showing basal minerogenic layers.

Dating

The 5 radiocarbon dates were calibrated to a calendar year timescale. An age-depth relationship (Figure 12) was drawn up using Clam software (Blaauw, 2010). The dates for the last 1000 years were inferred from the atmospherically deposited Pb profile recorded in the geochemistry analyses. Pb peak events were correlated with well-dated radiocarbon chronologies of Pb records from nearby lakes (Bindler et al, 2011).

The sedimentation rate increases at c. 4000 years ago, reflecting increased rainfall in the region during the late Holocene (Figure 12). The reduction in sedimentation rate that can be observed at c. 2000 years ago is a likely consequence of the compression of the upper peat layers due to modern drainage activities.

Table 1. Radiocarbon Dates calibrated into calendar years using Clam software (Blaauw, 2010).

Långhultamyren	**Depth (cm)**	**^{14}C years BP**	**Cal. BP**	**Probability**
(1950)				
0	-70			
Pb Date	18		100	
Pb Date	30		930	
LuS 17795	50	1565 ± 30	1380-1530	95.4%
LuS 17796	110	2290 ± 35	2155-2355	95.4%
LuS 17468	150	2660 ± 35	2735-2850	95.4%
LuS 17469	321	3550± 40	3715-3930	90.8%
LuS 17470	450	6825 ± 50	7575-7755	94.3%

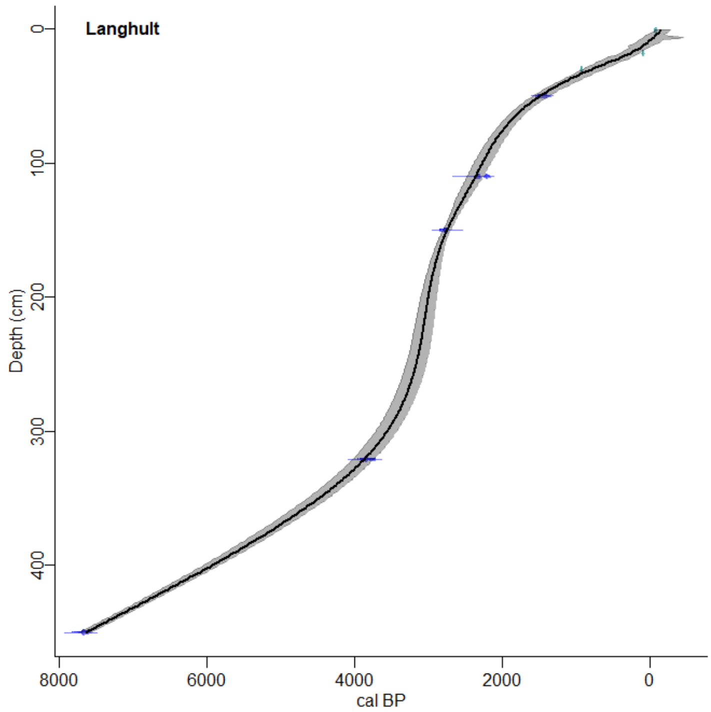

Figure 12. Age-depth relationship using Clam software (Blaauw, 2010).

Charcoal

The charcoal results were relayed into a Microsoft Excel spreadsheet. For the main pollen profile, Image J revealed the total area of charcoal, as well the areas of each individual charcoal piece, and a numerical count of charcoal fragments within each sample (Figure 13). The charcoal concentration for each sample was then calculated by dividing the area of charcoal by the total volume of sediment producing concentration in mm^2/cm^3 (Whitlock and Larsen, 2002). Results are presented on the pollen and plant macrofossil diagrams (Figures 14, 15,16) with photographs of selected pollen types on Figures 17,18,19,20,21,22. The pollen results for the marginal core are on Figures 23 and 24.

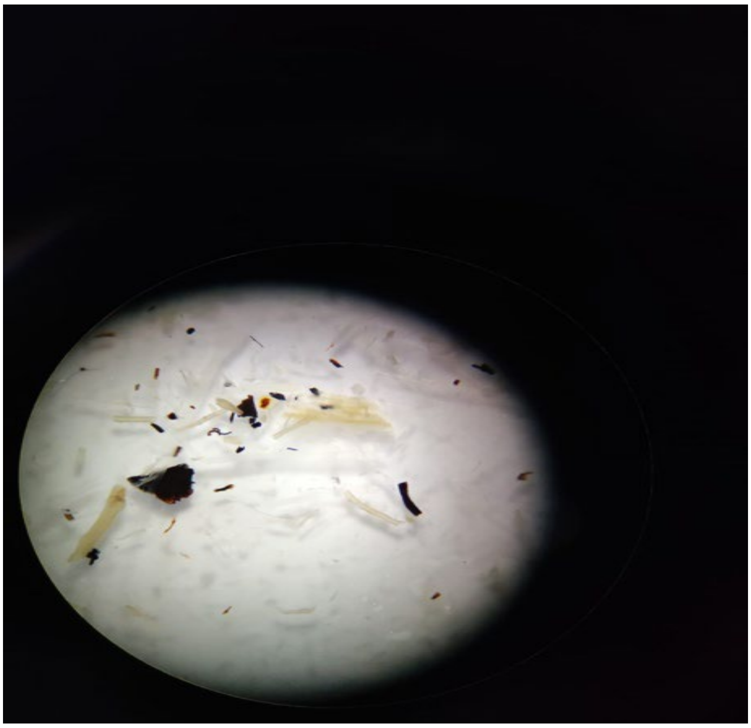

Figure 13. Charcoal fragments in the pollen sievings, photographed and area mm^2/cm^3 estimated using Image J.

Interpretation

Main Profile - Pollen, plant macrofossils and fire history

The vegetation of the non-forested parts of the wetland has shown many changes during the last seven and a half millennia. The current vegetation on the peatland is preceded by at least 7 previous phases that can be distinguished from the pollen diagrams (Figures 14,15,16).

1. A species-rich wooded fen (base c. 7700 – 5600 years ago) with initially high *Alnus* pollen percentages succeeded to a *Betula* dominated one with *Salix, Frangula*, Poaceae, Cyperaceae and Polypodiaceae (Figures 14,15). Macrofossils of *Pinus sylvestris* (stomata), *Betula* spp. (buds, twigs, flowering bracts, leaves) and *Alnus* (woody catkins) and pollen accumulation rate values exceeding 2000 grains/cm^2/year for *Pinus* and *Betula* and 250 grains/cm^2/year for *Salix* (Hättestrand et al., 2008) are

strong evidence that these trees were growing on the wetland surface (Figure 16). Sedimentary charcoal is consistently recorded suggesting summer droughts are associated with a natural fire regime. The higher ground surrounding the mire had a diverse tree pollen assemblage comprising both temperate and boreal species (Figure 14). *Pinus, Betula, Quercus, Tilia, Fraxinus, Ulmus, Betula, Alnus, Corylus, Frangula, Salix* and traces of C*arpinus* were recorded. Light-demanding herbaceous taxa are recorded (Poaceae, Cyperaceae and Brassicaceae) in the initial communities with Polypodiaceae (Figure 15). The site was a fen fed by nutrient-rich groundwater, which still flows near to the sample site at the base of the peat (Figure 25).

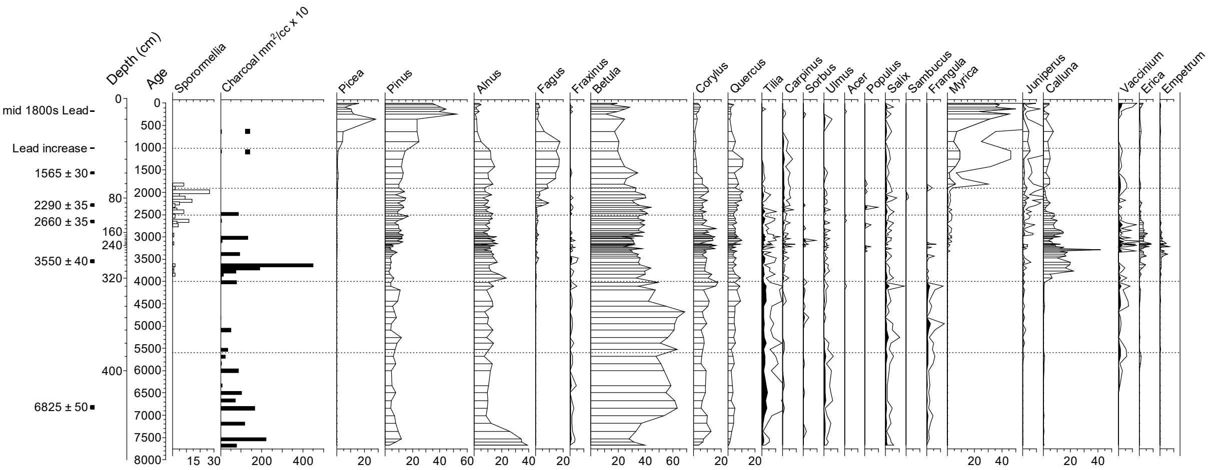

Figure 14.
Pollen percentage diagram showing major trees, shrubs, *Sporormiella* fungal spores, and sedimentary charcoal area (mm^2/cm^3 x 10). White outlines on selected taxa are exaggeration of the scale x 5. Dots represent small values of sedimentary charcoal.

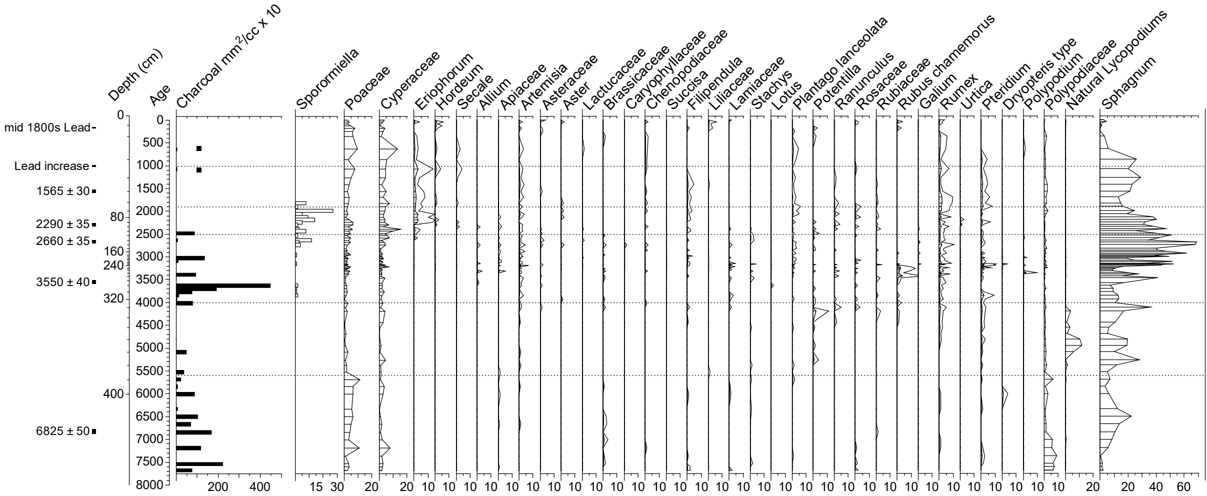

Figure 15. Pollen percentage diagram showing major herbs, *Sporormiella* fungal spores, ferns, *Sphagnum* and sedimentary charcoal area (mm^2/cm^3 x 10). White outlines on selected taxa are exaggeration of the scale x 5. Dots represent small values of sedimentary charcoal.

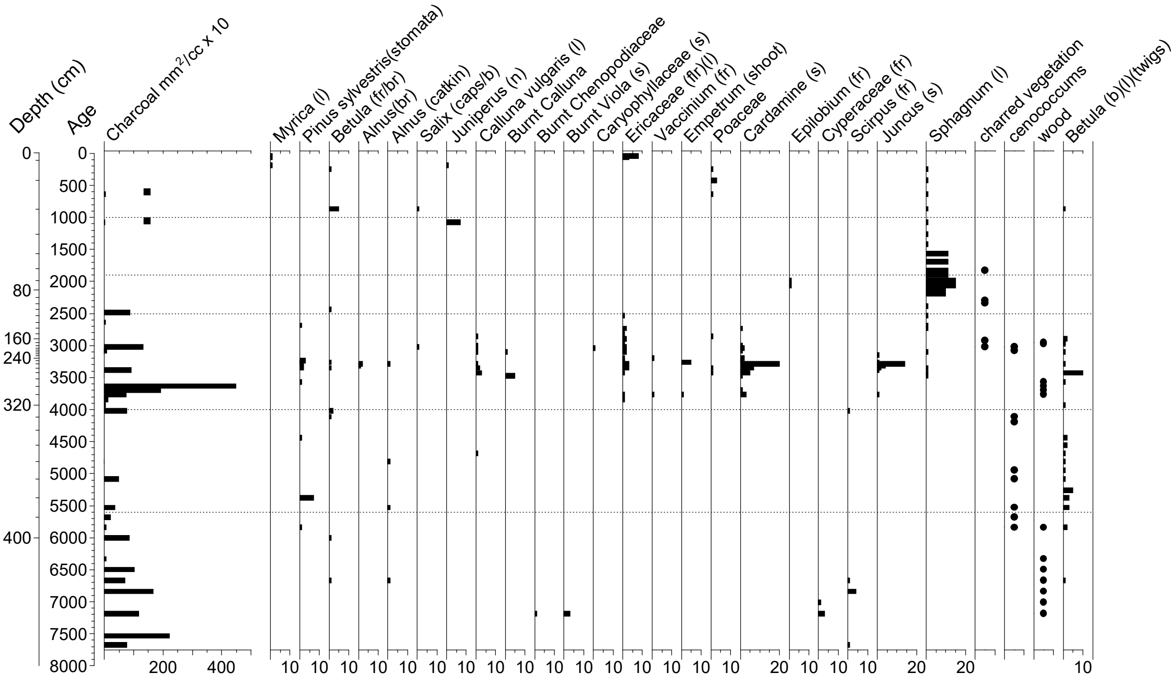

Figure 16. Plant macrofossil data: *Pinus sylvestris* stomata, charcoal area mm^2/cm^3 is x10. Symbols: b, bud scale; br, bract; caps, capsule; fr, fruit; flr, flower; l, leaf; n, needle; s, seed; sp, fungal spore. Dots represent small values of sedimentary charcoal.

2. Between c. 5600-4000 years ago, there is much less charcoal than before. The wetland is still a wooded fen community with macrofossils of *Betula, Pinus* and *Alnus* recorded (Figure 14) and supported by the pollen accumulation rates for these taxa. Ericaceae pollen frequencies have begun to replace Poaceae and Cyperaceae suggesting increased surface acidification, which is also indicated by the peak of natural *Lycopodium* (Figure 15). *Calluna vulgaris* leaves are present (Figure 16). This could be a natural successional process as peat thickness increases and the mire complex becomes more independent of the flowing groundwater (Figure 25).
3. Between c. 4000-2500 years ago, abundant charcoal is recorded again and the pollen record shows *Betula* has been partially replaced by *Calluna* (Figure 14). Ericaceae flowers, *Calluna vulgaris* leaves, including burnt shoots, *Vaccinium* sp. and *Empetrum* leaves are continuously recorded (Figure 16) with the first *Sporormiella* evidence for grazing animals and the expansion of a *Rubus chamaemorus* population (Figures 14,15). The site appears to become more open. There is an increase in *Sphagnum* spores and herbaceous taxa as the site probably becomes wetter (increased precipitation and water logging due to *Sphagnum* abundance and charcoal layers impeding drainage). *Myrica gale* is recorded at low levels for the first time in the pollen record (Figure 14). *Myrica* is associated with an oceanic climate with rainfall of up to 2000 mm per year and at least 200 wet days in any given year (Skene et al, 2000). Here at Långhultamyren, it has benefitted from increased light, increased water logging and increasing maritime climatic conditions characteristic of the late Holocene in this region (Skene et al, 2000). A peak is recorded of *Juncus* seeds (Figure 16). The combination of charcoal and the first occurrence of *Sporormiella* fungal spores strongly suggest that human activities affect the site for the first time through burning, and grazing of domestic stock. It is notable that this is

the first recorded evidence of *Sporormiella* suggesting that prior grazing by wild herbivores was negligible. Traces of *Fagus sylvatica* pollen are recorded. *Pinus* and *Betula* macrofossils consistently present (Figure 16), with the final *Pinus* stomata recorded c. 2500 years ago.

4. Between 2500 – 1900 years ago the site was a raised bog heavily influenced by human activities and the uplands were also being exploited. Poaceae and Cyperaceae pollen are more common than Ericaceae (Figures 14,15) and there is an increase in pollen from other open ground herbaceous taxa (Figure 15). There is evidence for cultivation with cereal pollen present of both *Hordeum* and *Secale*. The *Sporormiella* evidence suggests a heavy grazing period and an open environment both on the bog and the surrounding uplands. Some of the casualties are *Corylus, Tilia, Fraxinus* and *Ulmus* in the surrounding wooded areas. Poaceae, Cyperaceae and *Juniperus* (Figure 15) increase in importance as *Calluna* and *Sphagnum* decrease. This may be the period of most intensive human impact with local cereal cultivation of *Hordeum* and *Secale* (Figures 21,22) *Fagus sylvatica, Myrica gale,* and *Calluna vulgaris* pollen (Figure 16). There is only one level where *Betula* fruits and charcoal are recorded, with charred vegetation (Figure 16).
5. Between 1900 – 1000 years ago, there is a marked increase in *Fagus* pollen percentages, a short gap in cereal pollen record and a reduction in *Sporormiella* suggesting relaxation of grazing on the bog and a period of reduced human influence. *Myrica gale* and *Juniperus* substantially increase in importance likely due to a reduction in burning and browsing, possibly by goats (Skene et al, 2000).
6. Between c.1000 – present day, pollen of deciduous tree species, including *Fagus*, are in decline, in conjunction with indicators of sustained human activities (e.g. cereal cultivation). There are further increases in *Myrica* pollen together with *Picea abies*, *Pinus sylvestris* and *Juniperus.* In the last c. 100 years, the macrofossils record increased

shrubification with *Betula, Salix, Juniperus*, Ericaceae and *Myrica* on the bog surface with Poaceae (Figure 16).

The present importance of *Myrica gale, Pinus sylvestris* and *Picea abies* is a recent development over c. the last few hundreds of years (Figure 14). *Myrica gale* is often associated with oceanic climates, where rainfall can approach 2000 mm per year with at least 200 wet days in any given year. It is a light-loving plant, rarely found where there is less than 40% relative light and can form part of a succession to a fen forest woodland comprising *Alnus, Betula* and *Frangula* (Skene et al. 2000).

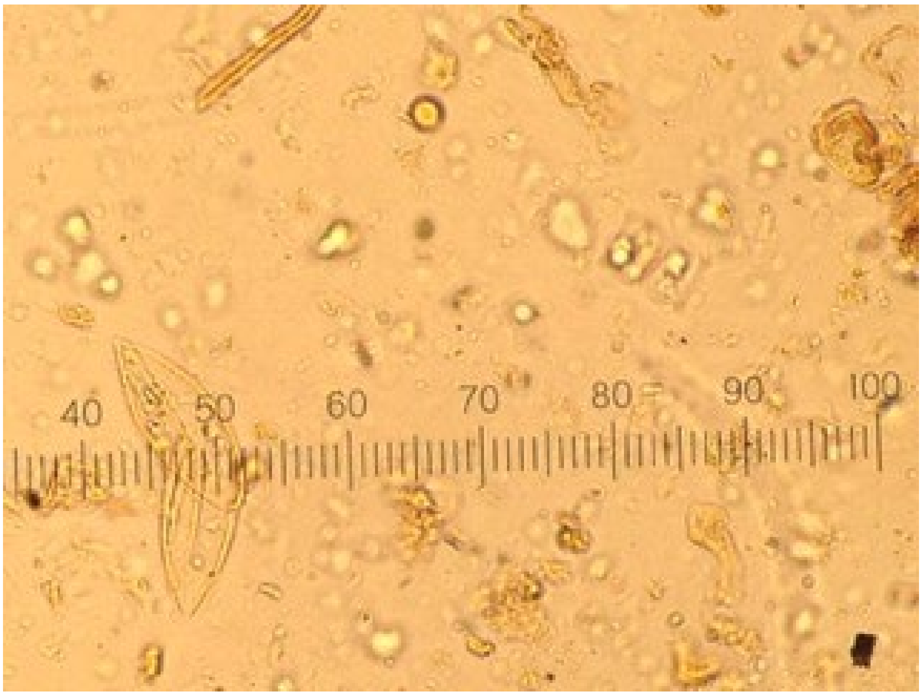

Figure 17. *Juniperus* pollen

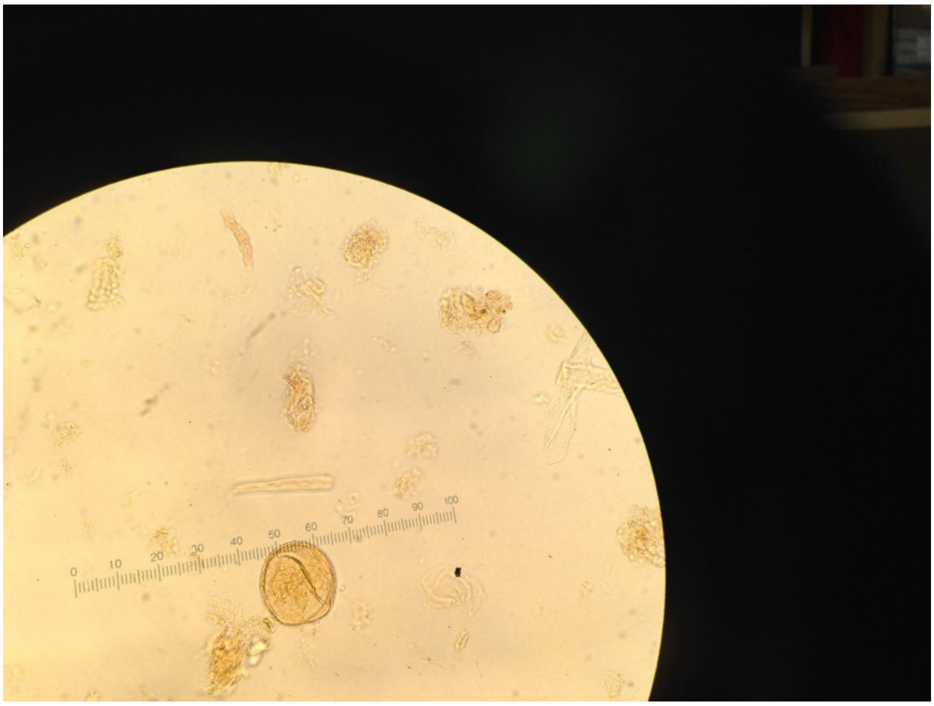

Figure 18. *Populus* pollen

Figure 19. *Fraxinus* pollen

Figure 20. *Calluna vulgaris* and *Plantago lanceolata* pollen

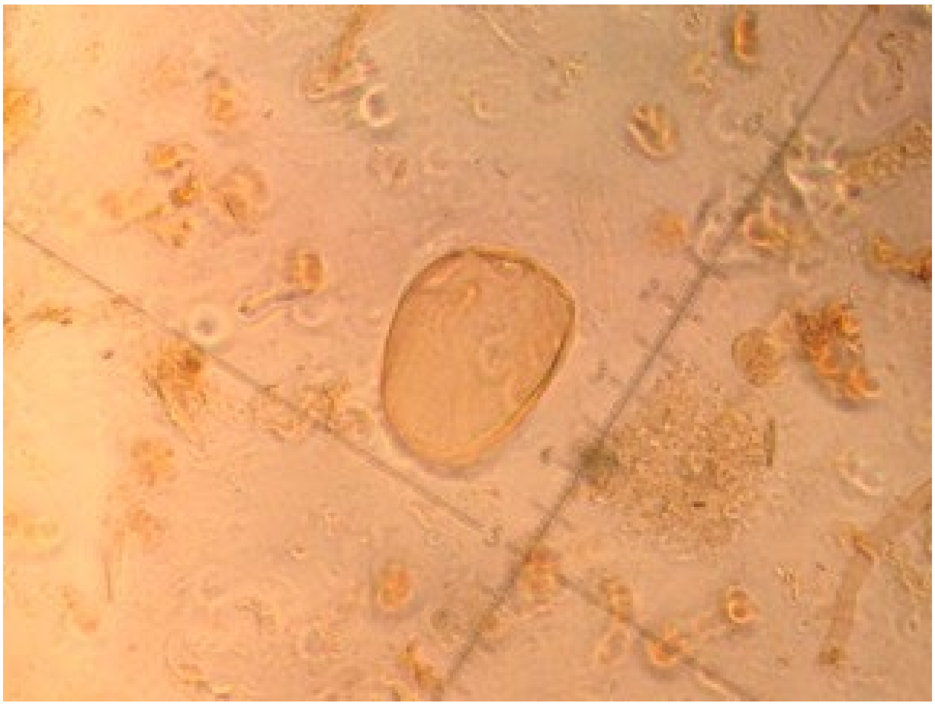

Figure 21. *Hordeum*-type cereal pollen

Figure 22. *Secale cereale* pollen

Marginal Core

The marginal core appears to have a record covering the last c. 2500 years (Figures 23,24). It has a higher proportion of herbaceous pollen, particularly *Calluna*, suggesting that the adjacent upland was largely deforested throughout its record. The records of *Hordeum* and *Secale* suggest that cereal cultivation was prominent on the local upland. The Pb record confirms the age of the latest *Myrica* expansion to the last few hundreds of years. The tree pollen values are generally similar to those recorded at the central core except for slightly smaller values for *Fagus*. The local uplands have therefore most likely had a similar forest history to more distant uplands, but with less *Fagus*.

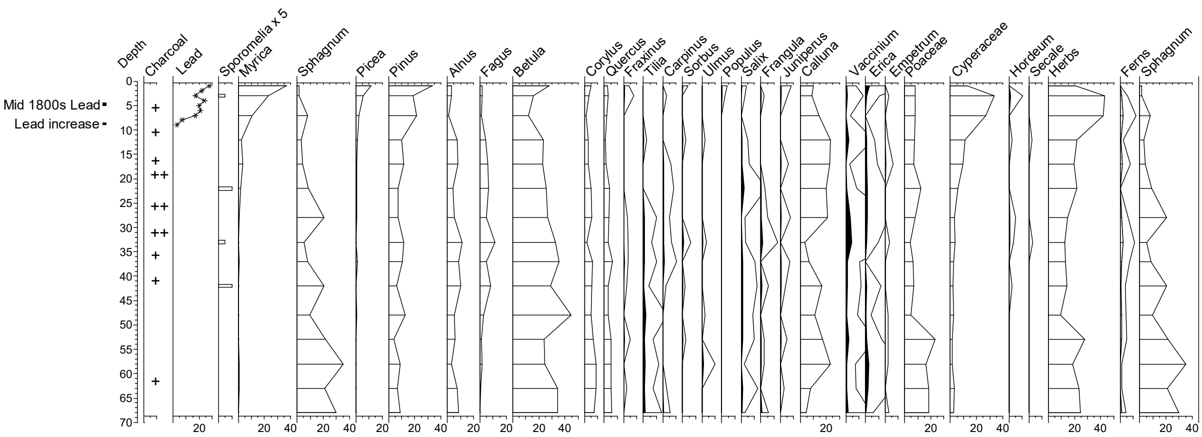

Figure 23. Pollen percentage diagram from the marginal site showing major trees, shrubs, cereals, herbs, ferns, *Sporormiella* fungal spores, *Sphagnum,* sedimentary charcoal presence and industrial Lead. White outlines on selected taxa are exaggeration of the scale x 5.

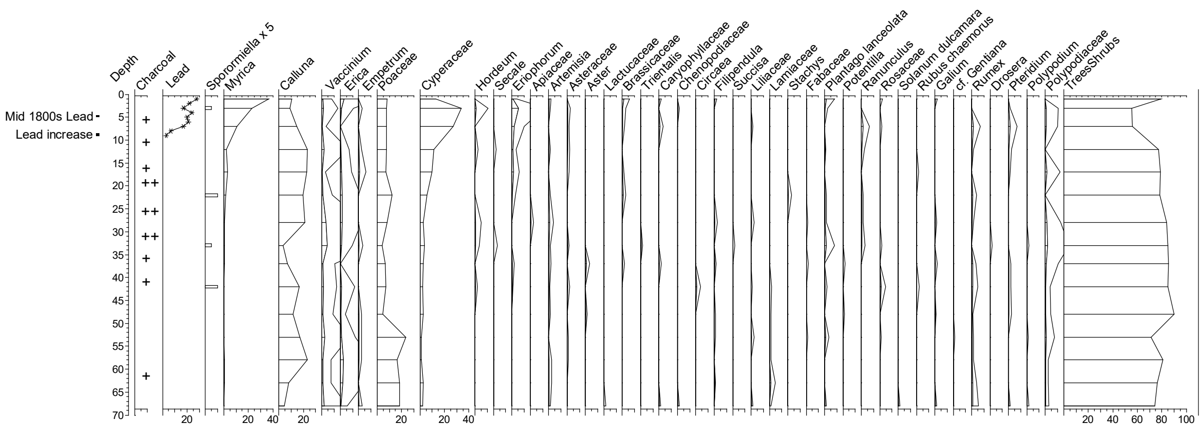

Figure 24. Pollen percentage diagram from the marginal site showing herbs, cereals, ferns, *Sporormiella* fungal spores, sum of trees and shrubs, industrial Lead and sedimentary charcoal presence. White outlines on selected taxa are exaggeration of the scale x 5.

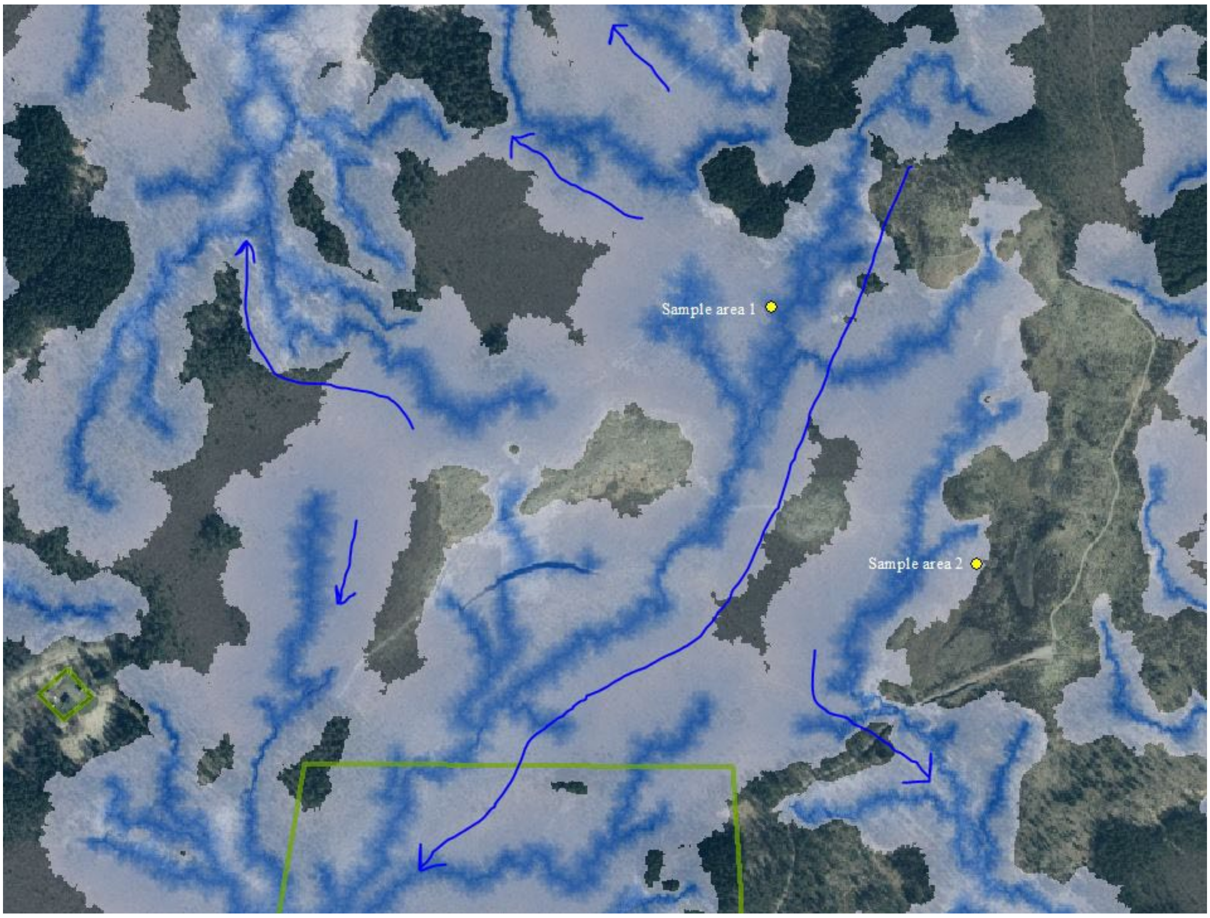

Figure 25. Main drainage patterns on Långhultamyren. Core locations marked.

Simplified summary of Långhultamyren vegetation history

1. 7700-5600 years ago. A species-rich wooded fen with *Alnus, Frangula, Betula* and *Pinus* scattered on the wetland surface and an open, diverse understorey including Cyperaceae, Poaceae, Polypodiaceae and Brassicaceae. Natural surface fires during dry summers.
2. 5600-4000 years ago. Wooded poor fen with (increased) surface acidification shown by increased Ericaceae and (natural) *Lycopodium*. Much less burning than before.
3. 4000-2500 years ago. Chiefly open raised bog with *Sphagnum, Calluna, Vaccinium, Empetrum* and *Rubus chamaemorus*. First signs of human activity with frequent burning and light grazing of domestic animals.

4. 2500-1900 years ago. Grazed raised bog with a few scattered trees and Poaceae and Cyperaceae more common than Ericaceae. Heavy grazing of domestic animals and occasional burning. First cereal cultivation on uplands.
5. 1900-1000 years ago. Period of reduced human influence. Relaxation from grazing on the bog and beginning of *Myrica* succession. Cereal cultivation continues on nearby uplands.
6. 1000 years ago until present. Shrubification of the bog with further spread of *Myrica*. Human impact shifts to planting of *Picea,* and attempts to drain the bog.
7. The marginal pollen profile suggests that the surrounding higher ground was species-rich forest comprising both temperate and boreal trees that probably survived until c. 1000 years ago (Figure 23). There was a subsequent loss of tree diversity, associated with human impact, with increases in *Picea*, *Pinus, Myrica*, Cyperaceae and Herbs (Figures 23,24) and decrease in *Fagus.*

Conclusions

- There have been several phases of changes in the vegetation community on the wetland which is a combination of anthropogenic use and a varying climate through time.
- The mire had trees growing on the surface (*Betula, Salix, Pinus, Alnus*) until at least 2500 years ago.
- Earlier forests surrounding the mire have been more diverse in the past, and with a larger proportion of temperate trees – *Quercus, Ulmus, Tilia, Corylus, Betula, Carpinus, Fraxinus, Acer, Populus, Salix, Sorbus* and *Frangula*.
- The plant community which today dominates the mire (*Myrica gale*) is recent, and only stretches back some hundreds of years. It is a drastic change to the bog surface, particularly with the incursion of *Picea* seedlings from neighbouring plantation forests.
- There have always been some open areas. This is seen in the early record of probable natural fires which show Poaceae and Polypodiaceae (which include

Polypodium, Dryopteris and *Pteridium*) during periods of sedimentary charcoal.

- There is a long history of anthropogenic use back to at least the Bronze Age when the first burning associated with people is thought to have taken place, alongside the *Sporormiella* fungal spore evidence for herbivores and significant increase in pollen of *Calluna vulgaris*. *Sporormiella* fungal spores are associated with the dung of animals.
- There is more intense human use in the Iron Age (2500 – 1900 years ago) with high *Sporormiella* fungal spores recorded. The first cereal pollen grains (*Secale cereale* and *Hordeum*) are present and the latter remains in the record until the last few hundred years. The arrival and subsequent expansion of *Fagus* is most probably associated with the demise of *Tilia, Fraxinus, Ulmus and Quercus* in the surrounding upland areas. *Alnus, Betula, Salix and Pinus* grew in places on the mire, but almost certainly also grew in the surrounding uplands.
- The recent growing over of the wetland by trees, particularly *Pinus* and *Picea*, and shrubs, primarily *Myrica*, is likely as a result of considerable reduction of grazing together with drainage, and lack of fire (Staffan Bengtsson, pers. comm.). The expansion of coniferous trees and seed spreading from plantation forests in the last few hundred years is likely to have impacted *Fagus.*

Management suggestions:

(a) The mire has shown a natural succession from wooded fen to open *Calluna – Sphagnum* bog but has also been influenced by millennia of human impact. Measures to keep the water table high and encourage maintenance of open conditions are recommended. Controlling the spread of coniferous trees, *Betula* and *Myrica gale,* should divert the woody succession that could take place. First natural, then anthropogenic burning was a feature of the site between c.7500 and 4000 years ago. Thus, burning and/or clearing might be a more practical tool for preventing these woody successions rather than increasing the current levels of domestic animals.

(b) The surrounding diverse deciduous forest community on the upland areas has only declined relatively recently, and could be replanted, if protected from grazing animals, particularly deer.

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Länsstyrelsen i Hallands län • Postadress: 301 86 Halmstad • Besöksadress: Slottsgatan 2
010- 224 30 00 • halland@lansstyrelsen.se • www.lansstyrelsen.se/halland