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Versatility as a cultural niche: palynological evidence on Iron Age and medieval land use on the Åland Islands

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ABSTRACT
The quantitative archaeological record of the Åland Islands (Finland) indicates a population boom in the mid-sixth century CE. Yet the number of palynological investigations on Åland is limited, resulting in a knowledge gap of anthropogenic landscape modification generated by the land use that followed the increased population. This article presents the results of a pollen analysis from Lake Lavsböle Träsk in central Åland, covering the period from the end of the Bronze Age into the modern period. The results of this study provide evidence of continuous land use throughout the Iron Age and the medieval period, and the population boom during the sixth century CE is indicated in the pollen signal. Altogether we argue for an economy based on cereal cultivation, animal husbandry, and maritime resource utilization (e.g. seal hunting, fishing, and fowling) as well as trading. The results indicate a society able to manage risks connected to their subsistence strategies, in which versatility seems to have had a key role.

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KEYWORDS
Cultural niche construction; land use; Iron Age; medieval period; Åland Islands; risk management; pollen

Introduction

The quantitative archaeological record of the Åland Islands (Finland) indicates and has commonly been argued to mirror a population influx during the Late Iron Age (hereafter LIA, 550–1050 CE; e.g. Callmer 2021; Dreijer 1979; Gustavsson et al. 2014; Hackman 1924; Ilves 2018a, 2018b, 2022; Kivikoski 1962, 1980; Núñez 1995; Roeck Hansen 1991; Tarsala 1998; Tomtlund 1999). This is interesting, as studies from northern Europe have indicated that a demographic change occurred in this period, likely as a result of a climate crisis. The LIA began with an environmental crisis in the mid-sixth century CE (Büntgen et al. 2016; Gräslund 2007; Gräslund and Price 2012; Sigl et al. 2015), often referred to as the Late Antique Little Ice Age. The climatic change during the Late Antique Little Ice Age has been argued to have resulted in demographic changes as well as land use adaptations (Bajard et al. 2022; Gräslund and Price 2012; Löwenborg 2012; Oinonen et al. 2020; Peregrine 2020; Tvauri 2014; Westling et al. 2022). The LIA was a period of change in northern Europe, in which agricultural activities changed with new tools, new cereal types, and a

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general intensification of agricultural activities (e.g. Behre 1992; Grabowski 2011; Lagerås and Fredh 2020; Lagerås and Larsson 2020). In addition, it was a period of dramatic social change as Christianity was adopted (Winroth 2012, 145–160; Antonsson 2020). Trade was extended and became far-reaching (e.g. Gaut 2014; Lindholm and Ljungkvist 2016) and, as a result, a general increase of resource extraction as well as partly new resources – most notably outland resources, such as furs, antlers, and iron (e.g. Hennius 2021; Lindholm and Ljungkvist 2016; Loftsgarden 2020; Nilsen 2017) – began to be utilized.

The population expansion visible in the archaeological material on Åland has also been situated in relation to the climatic events of the period (Ilves 2018a; 2018b; 2019, 44–45). However, while the number of registered ancient monuments[1] on the islands estimated to belong to the period is very high – there are around 450 LIA cemeteries with almost 11,000 visible burial mounds and about 90 known settlement areas, which strongly contrasts with the scant amount of ancient monuments estimated to belong to the previous periods of the Early Iron Age (hereafter EIA, 500 BCE–550 CE; Ilves 2018a, 2018b) – there are currently just about 200 radiocarbon dates available for the entire Iron Age of the Åland Islands (500 BCE–1050 CE) and very little information on changes in land use and socio-economic interactions during this period.

In this article, based on pollen analysis from Lake Lavsböle Träsk in central Åland (Figure 1), we assess land use during the Iron Age and the following medieval period (1050–1520 CE) to investigate if it is possible to detect anthropogenic landscape modifications in the pollen signal and to discuss how climate and socio-ecological processes interacted to shape Åland society. We also relate the results of our study with the available knowledge on Ålandic subsistence strategies. This investigation focuses on an area where

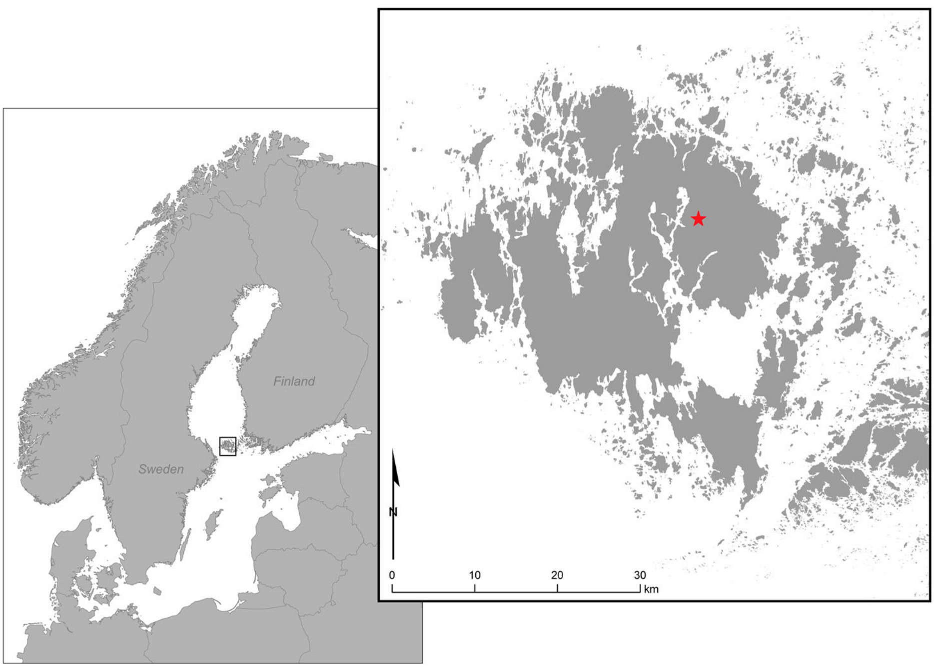

Figure 1. Map of the Åland Islands (Finland). The investigated area in the central part of the main island of Åland is marked with a red star. Map data: ©maanmittauslaitos.

the archaeological record suggests an especially dense population starting from the LIA, which allows study of how the interplay between nature and culture might have affected the people and their ways of utilizing the landscape.

Events, both climatic and epidemic, have been proven to have had a significant effect on societies in northern Europe in (pre-)historic times (e.g. Charpentier Ljungqvist, Seim, and Huhtamaa 2021). Our study contributes to this knowledge from a geographically less researched area. It also considers the times of affluence in relation to crises, thanks to the long-term nature of the palynological approach that was taken. Even if the consequences of the Late Antique Little Ice Age have been documented and the cultural responses in the densely populated areas of the central agrarian regions of northern Europe are relatively well known, there is still a knowledge gap regarding how geographically peripheral regions (such as Åland) were affected by this event.

This study aims not only to explore past socio-ecological processes but also to discuss active risk management on Åland, that is, the ability to respond to external changes by adapting and altering cultural activities, such as agrarian practices (e.g. Hatlestad, Wehlin, and Lindholm 2021; Marston 2011; Winterhalder, Lu, and Tucker 1999). To discuss this, we approach our results through cultural niche construction theory (e.g. Eriksson 2014; Laland, Matthews, and Feldman 2016; Matthews et al. 2014; Odling-Smee, Laland, and Feldman 2003; Ready and Holton Price 2021; Whitford 2019). This theoretical approach highlights adaptations and feedbacks within socio-ecological systems (e.g. Odling-Smee, Laland, and Feldman 2003) between the Åland population and their environment. By identifying changes in these systems, we are able to interpret and discuss strategies of subsistence within past societies on Åland (see McClure 2015; Odling-Smee et al. 2013; Ready and Holton Price 2021). Previous studies of cultural effects on societies in the northern hemisphere have shown that high levels of adaptability and a versatile economy have been the baseline for continuous settlement, even in times of hardship (Bajard et al. 2022; Oinonen et al. 2020; Westling et al. 2022). With this study, we attempt to evaluate if the Ålandic population made use of risk management in regard to their subsistence strategies, especially during times of hardship, such as the Late Antique Little Ice Age period and the following social transformation during the LIA, as reflected in archaeological material and the pollen record.

Study area

The Finnish, Swedish-speaking, autonomous Åland Islands are situated at the southernmost end of the Bothnian Bay in the Baltic Sea between the mainlands of Sweden and Finland (Figure 1). Lake Lavsböle Träsk is situated in the parish of Saltvik at 17.7 masl; with a generalized land uplift of about 5 mm per year (Ekman 2017), the lake should have been isolated from the Baltic Sea about 3,500 years ago. The bedrock is made up of viborgite, a type of granite. In the study area, the terrain is hilly, with a topographical variance of *c.* 8.5–38.5 masl. The landscape around Lavsböle Träsk today is mostly made up of a mixed forest that extends down to the shoreline (Figure 2).

Archaeological setting

The majority of ancient monuments from the LIA on Åland have been identified in relation to present-day agricultural areas. Since Åland is mostly composed of rocky terrain, soils

Figure 2. Photographs from Lake Lavsböle Träsk showing the vegetation that surrounds the lake today.

suitable for growing crops are scarce and typically limited to areas situated less than 5 metres above the current shoreline. Even as late as the eighteenth century, the cultivated lands constituted only about a third of the current total (Jaatinen, Peltonen, and Westerholm 1989, 27). Therefore, locations of current agricultural areas that were accessible during the LIA were also favoured and have a clear connection to known archaeological sites from the period. This connection between present-day agricultural areas and archaeological traces from the LIA is especially evident in the current region of study (Figure 3). There are over 50 LIA monuments registered in the radius of 3 km from Lake Lavsböle Träsk, most situated on the southern side, scattered around contiguous farmlands at about 2 km distance from the lake. Notably, the traces estimated to belong to the EIA are scarce in this region.

Immediately adjacent to the north-eastern shore of Lake Lavsböle Träsk, there is a limited agricultural landscape stretching all the way to the shoreline. Two smaller LIA cemeteries – with 45 and 33 visible grave mounds, respectively – have been documented in between these agricultural fields. There are also a couple of so-called stone foundation houses typical of the LIA Åland (see Ilves 2018a) documented in connection to these burial grounds. None of these sites have been investigated.

North of Lake Lavsböle Träsk, at a distance of 2 km from the lake, on the northern tip of the neighbouring lake of Åsgårda Träsk, there is another limited area with agriculturally suitable soils and adjacent (albeit not investigated) LIA cemeteries. There are two smaller burial grounds with only three and 17 visible burial mounds, respectively, and a larger cemetery with 80 burial mounds.

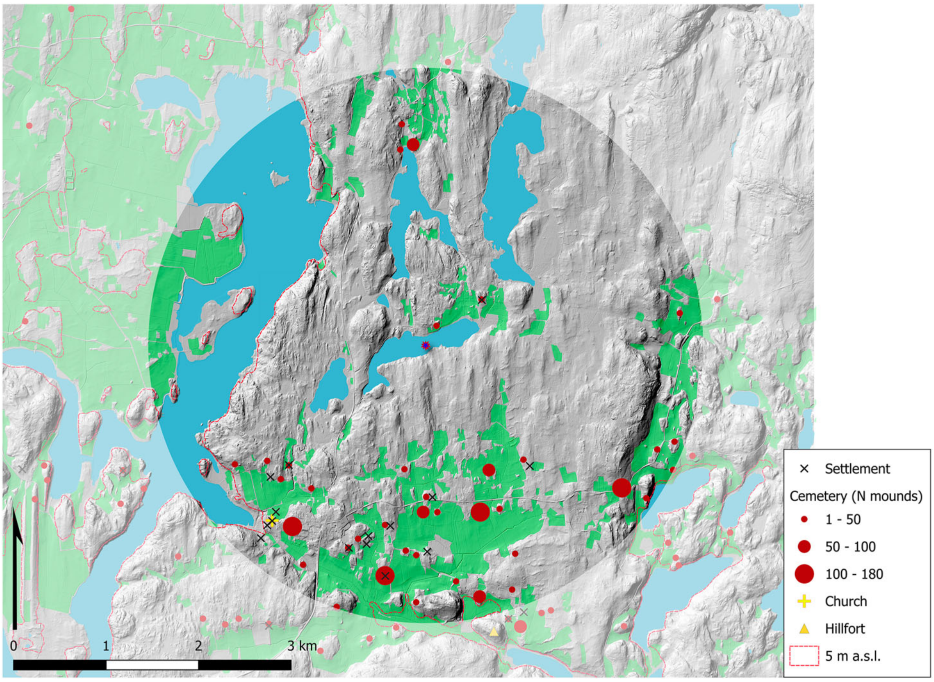

Figure 3. Landscape and Late Iron Age monuments around Lake Lavsböle Träsk. Green areas mark agriculturally suitable land and the asterisk in the middle of Lake Lavsböle Träsk stands for the coring site; a 3 km radius from the coring site is highlighted. Map data: ©maanmittauslaitos.

The area west of Lake Lavsböle Träsk is rocky and devoid of agriculturally suitable zones; no LIA monuments have been discovered in these territories. The area east of Lake Lavsböle Träsk is also characterized by the hilly terrain that is empty of LIA traces. However, at a distance of about 2.5 km eastward, farmlands commence and one LIA cemetery with 34 visible grave mounds has been registered in a zone fitting within a radius of 3 km from the lake. One of the graves was excavated a hundred years ago (Hackman 1927), revealing a rather remarkable Viking Age (800–1050 CE) burial, which due to the abundance and composition of discovered weapons has been assigned to a warrior.

The area south of Lake Lavsböle Träsk has the densest concentration of registered LIA monuments on the islands. To the south-west, about 2 km from the lake, in the village of Kvarnbo and by the medieval church of Saltvik, there is the largest LIA burial ground documented on Åland. This cemetery has 180 registered burial mounds and 14 have been archaeologically excavated, with find material typologically dating from the seventh until the eleventh century (Karlsson 1976, 1981). Adjacent to this burial ground, LIA and early medieval settlement layers have been documented around and under the church of Saltvik. These traces, registered as separate ancient monuments (see Figure 3), belong together with each other and with a large LIA settlement site immediately north of the church, so-called Kvarnbo Hall, which was discovered and archaeologically investigated in the 2010s (e.g. Ilves 2015, 2018b; Ilves and Darmark 2020). The Kvarnbo Hall site is an elite settlement with traces of dwelling houses and a large longhouse. Through extensive radiocarbon dating (see Ilves and Darmark 2020,

Table 7.1) as well as diagnostic artefacts (Ilves 2015), the site has been dated from the very beginning of the LIA to the end of the period, and understood as an autonomous hall farm with involvement in trade as a background for its social position (Herschend 2022, 232–234).

A few hundred metres north of Kvarnbo Hall, on the northern edges of the same agricultural zone, there is another archaeologically investigated settlement site with a high-status character: Kvarnbo-Kohagen. Both artefact-based chronology and radiocarbon dating place the active use of this site mainly to the Viking Age and the beginning of the medieval period (Ilves 2018a). Nearby, there are further indications of a settlement in the shape of a stone foundation house and smaller LIA cemeteries with a total of 89 visible grave mounds; 13 graves have been investigated with typologically dated finds covering the entire LIA (see also Dreijer 1959).

The densest concentration of LIA monuments, however, is directly south of Lake Lavsböle Träsk; there are numerous cemeteries and settlements within a distance of 3 km. Furthermore, the largest LIA hillfort on Åland – Borge in Borgboda, with an enclosed area of over 3 ha – is situated on the border of this area. Among the cemeteries in this region, there are smaller (with up to 50 mounds), mid-sized (with up to 100 mounds), and very large (with over 100 mounds) burial grounds, with a scattering of adjacent LIA dwelling sites (see also Figure 3). Few sites have been excavated; among these, there is the largest cemetery in this area: Kvarnbacken with 140 burial mounds. All the mounds were investigated over half a century ago (Kivikoski 1963; see also Gustavsson et al. 2014). The oldest burials in this cemetery were dated to the beginning of the LIA, while the youngest, in the shape of rectangular stone settings empty of finds, have been argued to represent early Christian burials dating to the beginning of the medieval period. Another large cemetery, with 113 visible grave mounds (seven investigated), is only about a kilometre westward from the Kvarnbacken burial ground and a kilometre eastward from the largest of the LIA cemeteries on Åland, by the church of Saltvik (see also above and Figure 3). Furthermore, 1.5 km eastward from the Kvarnbacken burial ground, at a distance of 2.5 km from Lake Lavsböle Träsk towards the south-east, there is yet another large burial ground, with 104 mounds (nine of which have been investigated). Thus, of the 13 large LIA cemeteries on Åland with over 100 visible grave mounds, four are situated in the current study region. In addition, there are four smaller cemeteries with a total of 87 visible grave mounds adjacent to the agricultural areas situated south-east of Lake Lavsböle Träsk.

In sum, the quantitative archaeological data from around Lake Lavsböle Träsk suggest a very dense population in this region emerging during the LIA. In contrast, the use of this region during earlier periods of the EIA is almost invisible.

Material and methods

Coring

The analyzed core was retrieved in 2020 from Lake Lavsböle Träsk (N6704207, E117795, ETRS-TM35FIN). A 215 cm-long lake sediment core was collected in the central parts of the lake using a piston corer. The water depth at the sampling location measured 720 cm. The lake was chosen due to its location, as it was the only site which offered the opportunity to implement pollen analysis for the region in question. The lake is large, about 29 ha, and oblong, about 500 m in width and 1 km in length. According to Jacobson and Bradshaw (1981), the pollen signal should thereby represent an extra-local and regional pollen signal (see also Sugita 2007a, 2007b for calculations on pollen source areas and landscape reconstruction models).

Sampling and analysis

The sediment consists of a homogenous and structureless coarse detritus gyttja. The organic matter has been measured by loss on ignition (LOI) by combusting the material at 550 °C for a period of 4 h. Magnetic susceptibility was measured following the standard procedure (Bengtsson and Enell 1986). The core was subsampled every second centimetre and prepared using the standard method of 10% HCl, 10% NaOH, and acetolysis (Moore, Webb, and Collinson 1991). Magnification between 20x and 100x, using immersion oil and phase contrast, was utilized during the identification process. Altogether, 106 levels were counted from the core, and a minimum of 500 arboreal grains were counted for each level. Spores and charcoal and soot particles were likewise counted alongside pollen. The charcoal was divided up into small particles (10–30 µm) and large particles (>30 µm). The identification of pollen grains and spores was made following Faegri, Kaland, and Krzywinski (1989), Moore, Webb, and Collinson (1991), Reille (1992, 1995), and Beug (2004). Separation of *Cannabis* and *Humulus*-type pollen was based on size class. Grains 25 µm or under have been classified as *Humulus*. Grains equal to or greater than 30 µm have been classified as *Cannabis*. Grains that fall between these (25–30 µm) have been classified as *Cannabis*/*Humulus*-type. The results are presented as percentages, where the pollen sum (P) is based on terrestrial pollen. Spore percentages have been calculated based on the pollen sum (i.e. P + spores). The same method was used to calculate the percentages of aquatics (P + aquatics) and charcoal and soot particles (P + charcoal & soot). Absolute frequency values were calculated for terrestrial pollen, using the standard method of the exotic-marker technique (with added *Lycopodium clavatum* spores) following Faegri, Kaland, and Krzywinski (1989, 83). This means that the counted pollen grains have been multiplied with the total number of added Lycopodium spores and divided by the counted Lycopodium spores counted on that specific level.

Pollen percentage and absolute frequency diagrams were produced in R (version 4.0.5; R Core Team 2022), using the rioja-package (version 0.9-26; Juggins 2020). Pollen assemblage zones (PAZs) were calculated through a CONISS zonation analysis, based on terrestrial pollen using the vegan package in R (version 2.5-7; Oksanen et al. 2020).

Chronology

The core has been dated with six radiocarbon dates from the Tandem Laboratory at Uppsala University (Table 1). The dates are based on sediment material, as terrestrial macrofossils were too few to be dated. An age-depth model (ADM) was calibrated (Reimer et al. 2020) and generated in R, using a Bayesian approach with the Bacon package (Blaauw and Christen 2011). The prior of the model was changed from the standard of an accumulation rate of 20 yr/cm to 10 yr/cm. The core was modelled with 44 sections and run with 8,625,000 iterations. The sediment surface was included as the year

Table 1. Core radiocarbon dates used to generate the age-depth model.

Lab code	Sample	δ13C (‰)	14C age BP	68.2% probability	95.4% probability
Ua-74303	60	−29.9	937 ± 28	1045–1053 CE (7%) 1060–1086 CE (20.1%) 1093–1105 CE (10.1%) 1118–1156 CE (30.6%)	1031–1167 CE (94.8%)
Ua-74304	101	−31.0	897 ± 28	1052–1078 CE (22.2%) 1156–1180 CE (24.3%) 1187–1211 CE (20.5%)	1044–1085 CE (27.5%) 1093–1105 CE (3.6%) 1119–1219 CE (64.2%)
Ua-74305	121	−31.5	1142 ± 29	777–780 CE (2.9%) 883–901 CE (15.6%) 916–975 CE (49.5%)	776–787 CE (5.8%) 828–858 CE (8.8%) 871–991 CE (80.6%)
Ua-74306	142	−30.9	1623 ± 29	415–437 CE (24.2%) 462–476 CE (13.1%) 497–533 CE (30.7%)	405–540 CE (95.4%)
Ua-74307	161	−30.6	1964 ± 29	22–83 CE (53.8%) 97–114 CE (14%)	38–11 BCE (8.6%) 2–124 CE (86.7%)
Ua-74308	210	−30.4	2447 ± 30	742–691 BCE (21.2%) 663–646 BCE (7.6%) 547–461 BCE (33.5%) 436–420 BCE (5.7%)	751–682 BCE (25.1%) 666–631 BCE (11.1%) 623–609 BCE (2.3%) 591–410 BCE (56.8%)

2020 CE in the ADM (−70 BP). Although the Ua-74303 sample (at a 60 cm depth of the core) resulted in an older ^{14}C age than the following Ua-74304 sample (at a depth of 101 cm) (Table 1), the application of Bayesian modelling mitigates the usability of this slightly deviant date as it fits into the ADM (Figure 4). Thus, all dates, along with the date of the sampling, were incorporated in the ADM, and the model provides a statistically valid result (Figure 4).

Results

Chronology

The ADM indicates a continuous sedimentary archive from *c.* 619 BCE until the sampling of the core in 2020 CE (Figure 4). The accumulation rate was calculated in the Bacon package (Figure 5), visualizing the rate of sedimentation in both years and depth (cm). There is a decline in the sediment accumulation rate around approximately 100–55 cm depth (Figure 5), which correlates to the transition period between the Viking Age and the earliest phase of the medieval period.

Calendar year calibrations of radiocarbon dates are often used arbitrarily. There are uncertainties in these ages, however, as also pointed out within this study. Due to the often-witnessed arbitrary use of ADM results, we provide a table with the results of our ADM in the analyzed levels of the core, displaying the uncertainties (Supplementary material 1). Henceforth, specified dates in the text refer to the mean values of each cm, as suggested by the ADM.

Stratigraphy

The sediment of the core consists of homogeneous dark brown gyttja throughout. The LOI mostly lay stable at around 30%, except during the EIA and the first half of the medieval period, when it rose to approximately 40–45% (Figure 6). The magnetic susceptibility

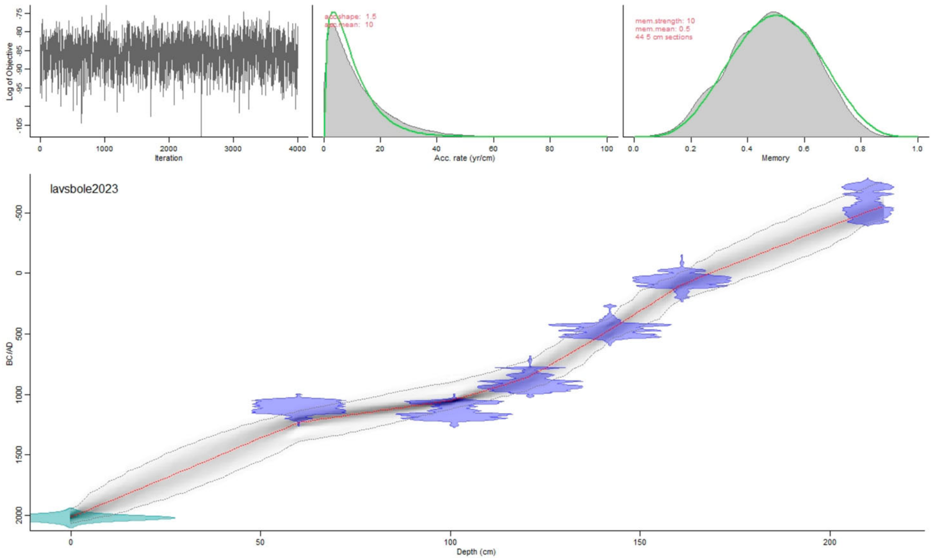

Figure 4. Age-depth model from the Lavsböle Träsk core.

was generally low but increased around depths of 140–124 cm (the LIA) at the same time as a drop in the LOI, which indicates clastic input into the lake due to soil erosion. In the uppermost part (the early modern and modern eras), there was a slight decrease in LOI, while there was a marked increase in magnetic susceptibility (Figure 6). This event is likely connected to soil erosion as well.

Pollen analysis

PAZ 1 (214–162 cm, c. *552 BCE–82 CE)*

The first PAZ indicates a forested region around the lake (Figures 7 and 8), consisting of a mixed forest: *Pinus* (*c*. 20–40%), *Betula* (*c*. 20–30%), *Alnus* (*c*. 10–20%), *Corylus* (*c*. 5–10%), and *Quercus* (*c*. 3–7%). In addition, towards the latter part of the zone, *Picea* is established as a dominant species, reaching almost 20% in the younger phase of the zone. Even if the region appears to have been heavily forested, there are taxa present in the pollen signal that indicate open patches, such as shrubs (e.g. *Sorbus* <1% and *Juniperus c*. 1–2%), but

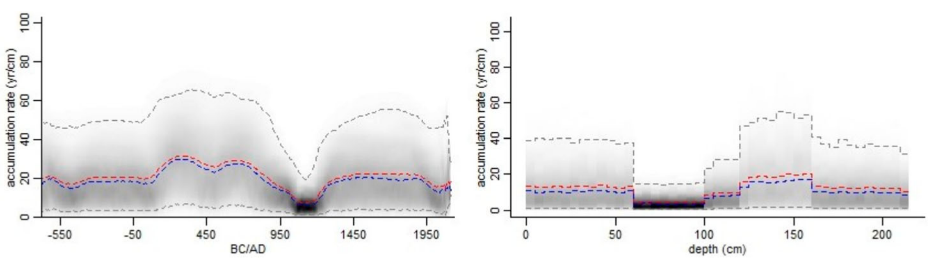

Figure 5. Visualization of the sedimentation rate. To the left, accumulation rate in years. To the right, accumulation rate in depth (cm).

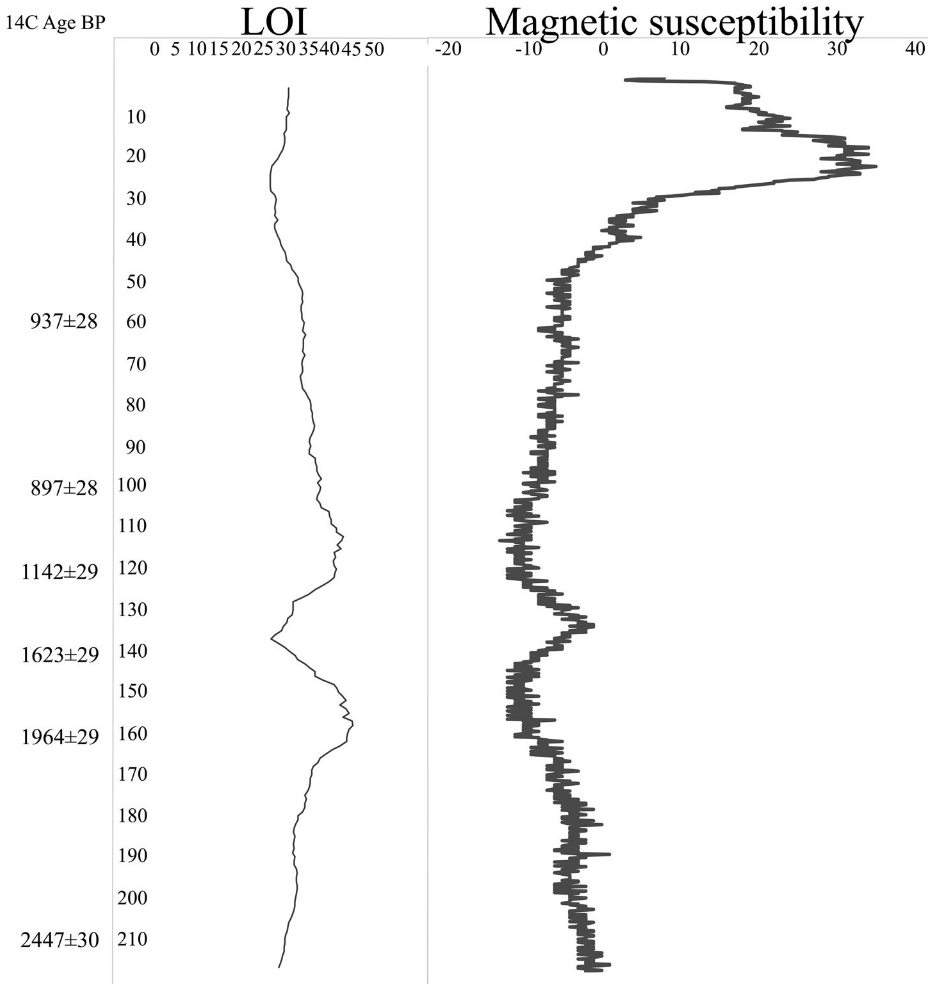

Figure 6. Graph showing loss on ignition and magnetic susceptibility.

also understorey species such as Cyperaceae (*c*. 0.5–1.5%), Poaceae (*c*. 1–3%), Apiaceae (<1%), *Filipendula* (*c*. 0.3–1%), *Artemisia* (<1%), and *Rubus* (<1%). There are additionally indications of cultigens with occasional *Hordeum*-type (<1%) and *Cannabis* (<1%).

PAZ 2 (160–142 cm, c. 108–464 CE)

The second zone is still heavily dominated by trees, but *Pinus* declines (*c*. 13–24%) in favour of *Picea* (*c*. 20–40%) and *Betula* (*c*. 20–30%). Thermophilous trees occur in noticeably lower percentages compared with the first zone. The understorey vegetation is similar to the one in PAZ 1. The number of large charcoal particles increases compared with the earlier zone. Poaceae (*c*. 0.5–3%), as well as *Calluna* (<1%), are present more frequently than before. *Juniperus* is present, with percentages reaching above 5% in this zone. Cerealia is more common in this zone and *Secale cereale* is visible at 0.13% around 268 CE and then again at 0.11% in 426 CE. *Hordeum*-type is similarly present at three levels (*c*. 0.13% in 268 CE, 0.10% in 347 CE, and 0.11% in 426 CE).

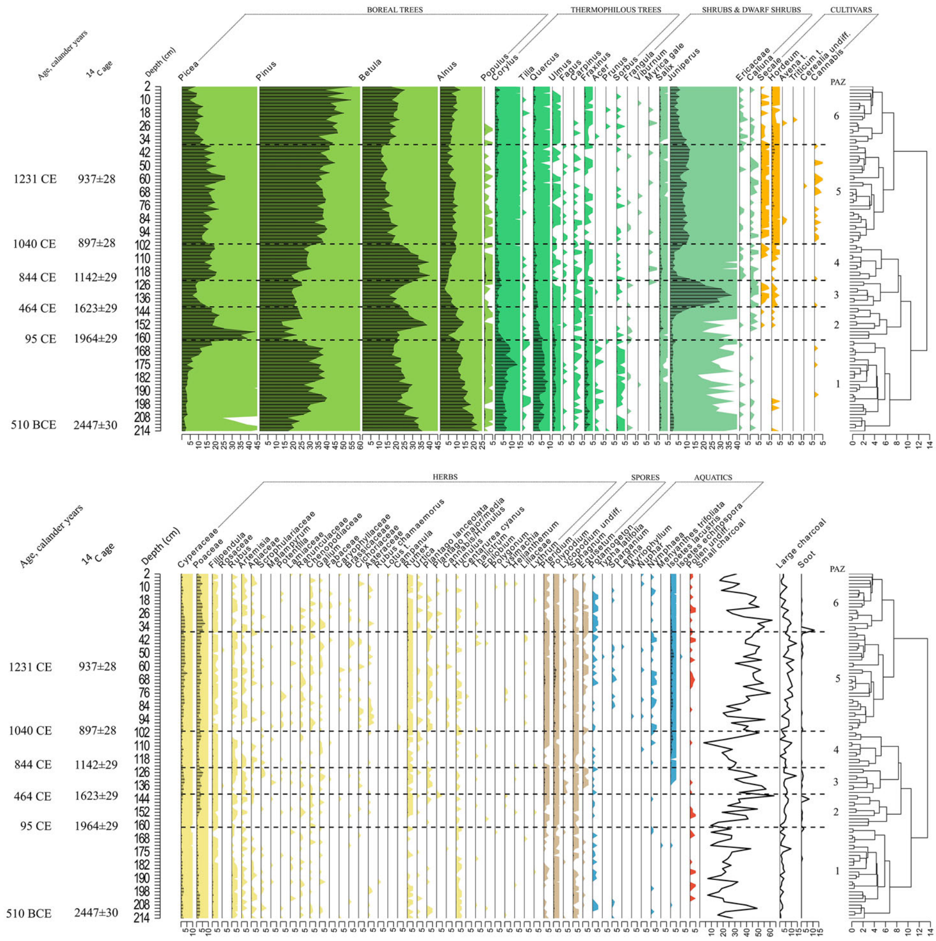

Figure 7. Pollen percentage diagram. Curves are exaggerated by 20×. The pollen data is available in Supplementary material 2.

PAZ 3 (140–124 cm, c. 503–796 CE)

In the third zone, all tree species decline (Figures 7 and 8), although *Pinus* only to a very small degree; the *Pinus* data likely reflects a regional pollen signal to a higher degree than in the case of the other tree species. *Juniperus* reaches an all-time high in the pollen signal (40% at its highest values). *Calluna* and *Plantago lanceolata* are common in the pollen signal for the duration of this zone, and herbs increase in general in this zone. The larger charcoal particles are still relatively high (*c.* 3–5%) and peak around 725 CE (14%). Both *Secale cereale* and *Hordeum*-type are present throughout this zone (<1%). The exception is the uppermost level (*c.* 796 CE), where both are absent. Cyperaceae (*c.* 1.5–3%) and Poaceae (*c.* 3–5%) increase slightly, compared with the previous zones.

PAZ 4 (122–102 cm, c. 828–1031 CE)

The pollen signal indicates a regrowth of the landscape around the lake in the fourth zone. *Juniperus* drops markedly, and cereals occur sporadically between *c.* 828 and 939 CE, with

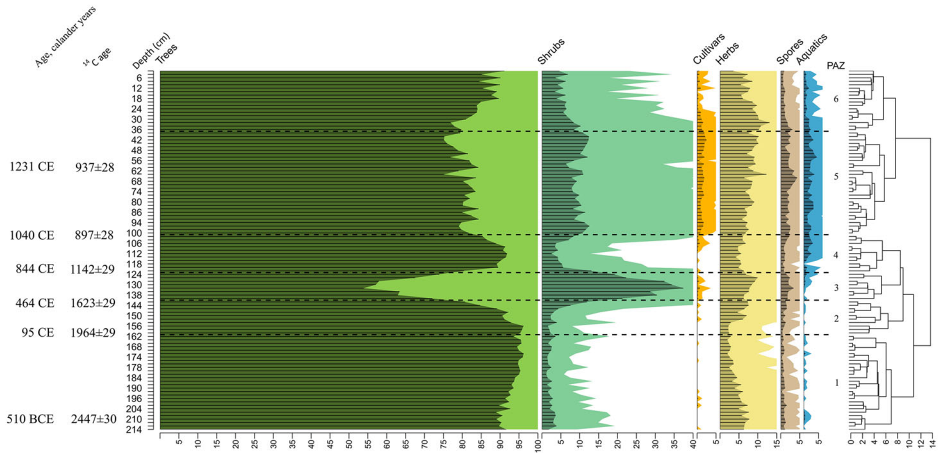

Figure 8. Summary diagram of pollen analysis presented in percentages. Exaggeration curves set to 20×.

only a few occurrences of *Hordeum*-type pollen. There is an increase in trees, especially *Betula* (*c*. 24–40%), a species that is often quick to re-establish itself in abandoned fields. Both *Juniperus* (*c*. 1.5–11%) and *Calluna* (<1%) decline, compared with the third zone, while Ericaceae increase (<1%). In the younger half of this zone (*c*. 949–1031 CE), both *Secale cereale* (<1%) and *Hordeum*-type (<1%) are again more steadily present in the pollen signal.

PAZ 5 (100–38 cm, c. 1048–1519 CE)

The fifth zone represents a long time span, covering the medieval period. Trees associated with the boreal forests are stable throughout this zone: *Picea* (*c*. 13–20%, peaking at 25% at 58–60 cm depth), *Pinus* (*c*. 35–40%), *Betula* (around 20% in the older part of the zone and decreasing to about 11% in the upper parts), *Alnus* (*c*. 5–10%), and *Populus* (<1%). Thermophilous trees decline and are represented mainly by *Corylus* (*c*. 1–2%) and *Quercus* (*c*. 0.5–1%). Meanwhile, *Juniperus* (*c*. 7–11%), *Calluna* (<1%), *Plantago lanceolata* (<1%), and Ericaceae (<1%) are present continuously. *Secale cereale* (<1%) and *Hordeum*-type (c. 1%) increase, compared with PAZ 4, and their values are stable throughout the period. *Cannabis* (<1%) appears and is present sporadically throughout the zone. *Avena*-type is also present at two levels (*c*. 1113–1122 CE, < 1%).

PAZ 6 (36–2 cm, c. 1545–1987 CE)

In the uppermost zone, *Picea* decreases to *c*. 10% (except at a depth of 4 cm, where it reaches 3.5%). *Pinus* (*c*. 40–50%) and *Betula* (*c*. 17–20%) increase in this zone. *Alnus* and thermophilous trees are present at levels similar to those in the previous zone. Shrubs decline, represented mainly by *Juniperus* (*c*. 3–6%), *Salix* (*c*. 0.5–1%), and occasional Ericaceae (<1%). The understorey resembles the earlier zones. Several species, such as *Plantago lanceolata* (<1%), Ranunculaceae (<1%), and Asteraceae (<1%), are present with lower frequency. The percentage of Poaceae is stable (*c*. 3–5%), while Cyperaceae decline slightly (*c*. 1–3%). Cerealia declines in this zone; *Secale cereale* (<1%) is markedly more sporadically present in the pollen signal, compared with PAZ 5, and *Hordeum*-type is present in lower percentages (>1% at 30–36 cm depth and thereafter <1).

Absolute frequency

The absolute frequency values show that the pollen percentage diagram is not misleading, as similar curves occur when the terrestrial pollen grains are calculated with added *Lycopodium clavatum* spores (Figure 9).

Discussion

Landscape changes

Early Iron Age

The oldest part of the pollen core covers the very end of the Bronze Age (1800–500 BCE) and the EIA, including PAZ 1 (*c*. 552 BCE–82 CE) and PAZ 2 (*c*. 108–464 CE). The region is densely forested during this period, composed of both boreal trees (*Picea*, *Pinus*, *Betula*, *Alnus*, and *Populus*) and thermophilous trees (*Corylus*, *Tilia*, *Quercus*, *Ulmus*, *Carpinus*, *Fraxinus*, and occasional pollen from *Fagus* and *Acer*). The understory vegetation is mostly made up of *Calluna* and Ericaceae, accompanied by *Juniperus* bushes. There are some cultivars present in the pollen signal: *Hordeum*-type is sporadically present in PAZ 1 and is accompanied by *Secale cereale* in PAZ 2.

Late Iron Age

During the LIA, there is a marked increase of *Juniperus* (PAZ 3), which indicates an opening of the forest canopy. This is not only seen in the pollen percentage diagram but likewise in the absolute frequency values, which shows that this marked increase is not an outcome of statistical nature (as percentage values are dependent on each other) but signifies a real change in the vegetation composition of the landscape. *Calluna*, *Rumex*, and *Plantago lanceolata*, alongside *Juniperus*, suggest that the landscape became more open than before and there is also a concurrent increase in microscopic charcoal particles. The opening of the landscape is interpreted as a likely result of grazing activities. Furthermore, there is an increase in Cerealia, showing anthropogenic land use close to the lake.

In the middle of the Viking Age (PAZ 4, *c*. 828–939 CE), there is a clear shift in the vegetation composition within the study area with a decline of anthropogenic indicators, especially visible in *Juniperus* and Cerealia. At the same time, there is an increase of trees, especially boreal trees (*Picea*, *Pinus*, and *Betula*), supported by both pollen percentages and absolute frequency values. Concurrently with the forest regrowth, there is a decrease of charcoal fragments in the pollen signal. From *c*. 959 CE, there is again an increase of anthropogenic influence, especially visible in a re-establishment of Cerealia cultivation.

Medieval period

The pollen signal reflects a continuum from the latest phase of the Viking Age. Cultivation of Cerealia (mostly *Hordeum*-type and *Secale cereale*) is continuous and there is also an increase of shrubs, while trees decline again – indicating an opening of the forest canopy. Species such as *Juniperus*, *Calluna*, and *Plantago lanceolata* increase, suggesting

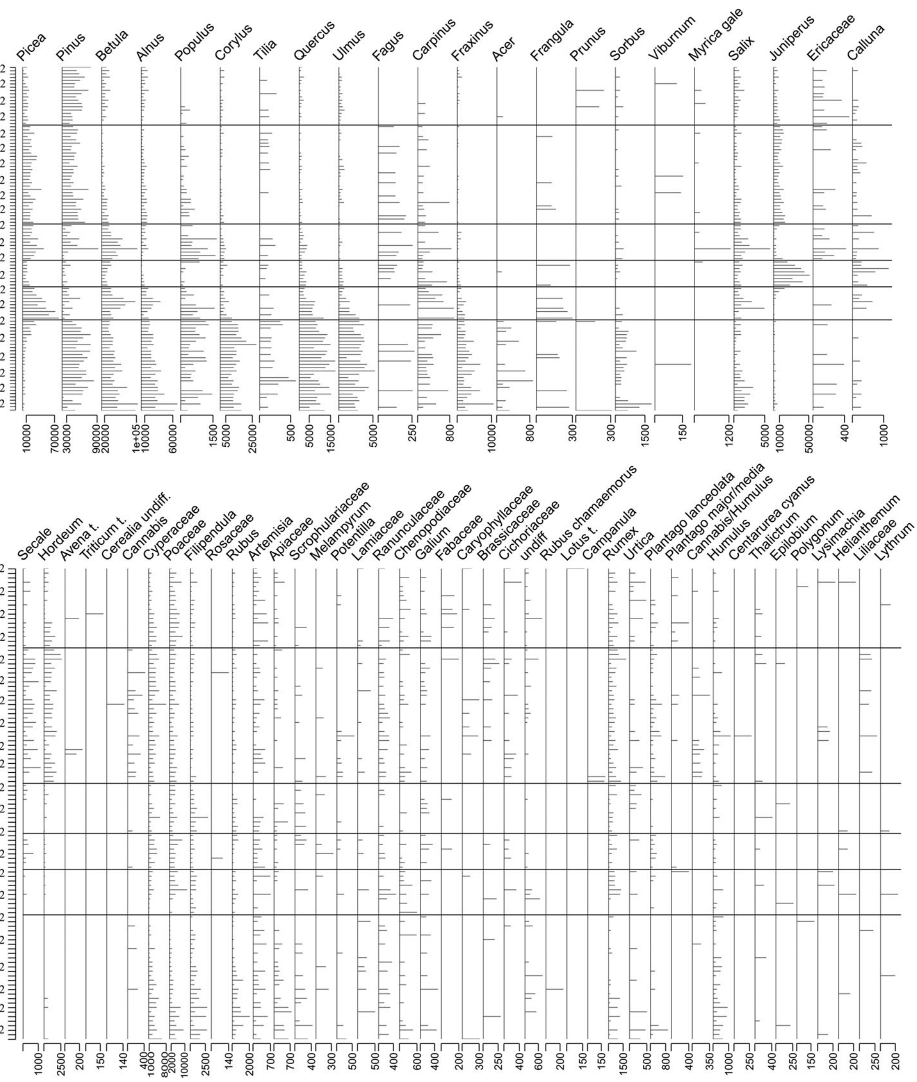

Figure 9. Absolute frequency values of terrestrial pollen grains.

a local increase of anthropogenic modification of the landscape around the lake. There are also a few occurrences of *Avena*-type pollen during the medieval period. Throughout the medieval period and into the early modern era, the pollen signal shows a somewhat standardized composition of species, compared with other agrarian regions in northern Europe during the same period (e.g. Emanuelsson et al. 2003; Rasmussen 2005; Wallin 1996), including other areas of Åland (Alenius, Ilves, and Saarinen 2022).

Land use

Early Iron Age

The archaeological record in the study area does not provide evidence of much human presence or activity during the EIA. The pollen signal does, however, indicate some possible anthropogenic modification of the landscape. *Juniperus*, *Calluna*, Ericaceae, Poaceae, and Cyperaceae are present continuously, implying open patches in the forest canopy. These open patches could originate from grazing activities. The earliest *Hordeum*-type grains present in the pollen signal are still to be considered uncertain as anthropogenic indicators, as some wild grasses can overlap in size and morphology with the cultivated *Hordeum*-type (Edwards et al. 2005; Hannon and Bradshaw 2000; Tweddle, Edwards, and Fieller 2005; Vorren 1986). However, in PAZ 2 (from *c*. 268 CE), the *Hordeum*-type grains are accompanied by the cultivated and morphologically distinct *Secale cereale* in the pollen signal, and these co-occurrences make the interpretation of the *Hordeum*-type grains during PAZ 2 as cultigens more plausible.

In general, the anthropogenic indicators increase slightly during the latest phase of the EIA (PAZ 2), as suggested by an increase in *Juniperus*, *Rumex*, and charcoal particles. In addition, Poaceae and Cyperaceae increase in this period, suggesting a higher level of landscape openness– probably driven by grazing and farming.

Late Iron Age

The archaeological record shows a clear increase in human presence during the LIA within the investigation area. The dense population suggested by the archaeological data is shown in the pollen signal as well. In the beginning of the LIA, there is an increase in species considered to be anthropogenic indicators, meaning that the human activities in the area were a driving force in modifying the vegetation composition. The increase of shrubs (especially notable in the *Juniperus* case) and herbs show that landscape openness increased. This is interpreted as the result of an intensification of land use built around animal husbandry and small-scale cultivation of Cerealia. Furthermore, there is an increase of charcoal, possibly linked to the burning of forest to generate pastures and fields.

Even if the first grains of *Secale cereale* are already present in the pollen signal in the transition from the EIA to the LIA, there is a clear increase of *Secale cereale* in the LIA (PAZ 3). It has been suggested that rye, *Secale cereale*, was introduced during the Iron Age due to the new climatic circumstances of the Late Antique Little Ice Age, as this crop is durable and able to withstand a cold and wet climate (see Westling et al. 2022; Westling and Jensen 2020). This interpretation also seems plausible for Åland, as the cultivation of rye clearly increases in the third PAZ (*c*. 539–762 CE). The pollen signal indicates an opening in the forest canopy through such species as *Juniperus*; this openness of the landscape, combined with species such as *Calluna* and *Plantago lanceolata*, is interpreted as a sign of animal husbandry. This increased level of anthropogenic modification of the landscape through agrarian activities further indicates that during the period of the Late Antique Little Ice Age, when demographic reorganization and decline have been noted in other areas in northern Europe, the Åland Islands appear to have thrived.

The LOI and magnetic susceptibility indicate soil erosion during the LIA, possibly as a result of anthropogenic modification of the landscape. Soil erosion could result from forest clearance (see Goudie 1995, 105–11; Simola 2018) implemented for agricultural reasons (e.g. generating fields; Goudie 1995, 106), but it could likewise be the result of heavy rainfall (Marzen et al. 2017).

After about 250 years of intensified land use around the lake, there was a rapid decline in anthropogenic indicators and an increase in trees in the Viking Age (from *c*. 828 CE).

There are still continued indications of some open patches and possible grazing represented through species such as Ericaceae, Poaceae, *Calluna*, and *Juniperus* (see Behre 1981)– although on a smaller scale than previously. Signs of cultivation are also present in the pollen signal (*Secale cereale* and *Hordeum*-type) but more sporadically. At the end of the Viking Age, however, from *c.* 959 CE onward, there is again an increase in anthropogenic influence on the pollen signal. This increase is most notable in cultivars.

Medieval period

The pollen signal that dates to the medieval period provides evidence of an agrarian landscape similar to that of the last phase of the Viking Age. The presence of *Juniperus*, *Calluna*, Ericaceae, and *Plantago lanceolata* is understood to indicate domestic grazing. Combined with grazing, the pollen signal shows that cultivation of cereals was an important aspect of the subsistence strategy during the medieval period. Similarly to previous periods, *Hordeum*-type and *Secale cereale* were the main cultivars during this period. There are also a few occurrences of *Avena*-type pollen, but either this species was cultivated further away from Lake Lavsböle Träsk, and therefore only occurs occasionally, or the cultivation of this cereal was simply not favourable or successful. Although on a small scale, *Cannabis* appears to have been grown as well, as it is more or less continuously present throughout the medieval period.

As there is an agrarian continuum in the pollen signal from *c.* 959 CE up until modern days, there is no evidence of a decline in agriculture or population during the medieval crisis (see Campbell 2016), which in many areas of northern Europe resulted in abandonment, being evident in different pollen signals compared with times of affluence (Fredh et al. 2019; Izdebski et al. 2022; Lagerås 2007; Svensson et al. 2022).

Cultural niche construction

All landscapes are complex but dynamic, and habitats never exist in an equilibrium – meaning that there is a constant exchange between organisms and their habitats, deriving from various disturbances (e.g. Holling 1973; Kulha et al. 2019; Kuuluvainen et al. 2017; Odling-Smee, Laland, and Feldman 2003). To understand the changes in the landscape around Lake Lavsböle Träsk from a cultural perspective, we apply cultural niche construction theory (hereafter CNCT), a development of cultural application of the ecological theory of niche construction (hereafter NCT; e.g. Clark et al. 2020; Kendal, Tehrani, and Odling-Smee 2011; Laland, Matthews, and Feldman 2016; Odling-Smee, Laland, and Feldman 2003), which has recently seen an increased application in landscape studies (e.g. Boivin et al. 2016; Eriksson 2014, 2016, 2023; Eriksson and Arnell 2017; Eriksson, Arnell, and Lindholm 2021; Hatlestad, Wehlin, and Lindholm 2021; Nikulina et al. 2022). We have chosen to use CNCT rather than the concepts of socioeconomic versatility or resource diversity, because we consider that agency should not be neglected when discussing the land use and subsistence strategies of past societies. CNCT is a fitting approach in this framework (see Kendal, Tehrani, and Odling-Smee 2011), and the application of CNCT to archaeological research has been shown to be useful in understanding the relationship between humans and their surrounding landscape (e.g. Eriksson 2023; Hatlestad, Wehlin, and Lindholm 2021).

We use CNCT to discuss and evaluate socioeconomic versatility, but also to analyze how anthropogenic land use was formed by – and shaped – the landscape. CNCT is not only a tool to describe socio-ecological processes, as this approach also highlights the agency of both people and ecological agents (e.g. Banks et al. 2011; Eriksson 2013, 2014, 2016; Whitford 2019). We would like to suggest that Åland was chosen as a residence by what seems to be a considerable number of people moving to the islands in the beginning of the LIA; this was not by coincidence but due to what these islands offered, namely, a chance to minimize risks in a time of hardship. While many settlements in northern Europe saw abandonment, likely due to changed external settings (e.g. Gräslund 2007; Oinonen et al. 2020), the Åland Islands saw an increase in population. We interpret this to be the result of the available economic versatility within this maritime landscape.

Zooarchaeological studies on Ålandic material show evidence of extensive maritime resource utilization, seal hunting in particular, during various historical periods (Kivikero, Gustavsson, and Storå 2020; Storå 2000, 2002; Storå et al. 2012; Storå and Lõugas 2005). A few osteological analyses implemented on material from the Ålandic LIA settlement sites further show that waterfowl was a substantial part of the subsistence strategy (Kangasmaa 2021; Kennebjörk 2011, 2014; Mannermaa 2018). Domestic fowl has been documented but not nearly in the same quantities as wild waterfowl, which exhibit great variation and include mainly larger species, such as the common eider and great cormorant. Zooarchaeological proxies, in line with our pollen analysis, further suggest that animal husbandry and grazing activities were part of the land use (see Gustavsson et al. 2014; Kennebjörk 2014; Lindblad 2014; Storå et al. 2012).

The cultivation of cereals was an important aspect of the economy, and it is likely that both *Hordeum*-type and *Secale cereale* were regularly cultivated (as suggested by macrofossil analyses; Lempiäinen-Avci 2021; Núñez and Lempiäinen 1992). Macrofossil analyses from the Kvarnbo Hall settlement site located in the current study area also show that *Avena* and *Triticum* occurred alongside *Hordeum* and *Secale cereale* (Andersson 2014, 2017). This settlement site, among others, serves as a good example of Åland also being well integrated in the long-distance trade (see also Ahola Frog and Lucenius 2014) that comprises part of the locals' subsistence strategies. The importance of trade in the LIA society of Åland is further evident in the amount of Oriental silver coins discovered from both the settlement sites and cemeteries. The largest treasure ever found on Åland, consisting of at least 859 Arabic silver coins struck between 739 and 874/875 CE and buried in an Oriental jug (Talvio 2002: no. 108), was documented in the current study region, close to Kvarnbacken cemetery south of Lake Lavsböle Träsk.

This versatile economy resulted in various modifications and adaptations of the landscape. The demographic reorganization of the Åland Islands itself can be argued as part of a cultural niche construction, as a new, emerging landscape offered new subsistence possibilities. Additionally, anthropogenic land use influenced and changed the landscape where the forest canopy was opened through deforestation – likely due to grazing activities and for the purpose of generating fields for cereal cultivation, perhaps through anthropogenic fires. There were also more long-lasting implements of the LIA niche-making on Åland, as physical aspects of the landscapes were established (e.g. visible grave mounds and stone foundations for houses as well as still-standing stone walls of hillforts). This means that people not only adapted to a new and harsh climate in the

LIA, but they also changed the newly settled areas through their activities, resulting in reciprocal causation, which is the very essence of CNCT (Eriksson 2023; Eriksson, Arnell, and Lindholm 2021; Odling-Smee, Laland, and Feldman 2003). CNCT may sometimes also be used to interpret and evaluate the success of socio-ecological systems, such as through risk management, as discussed below (Hatlestad, Wehlin, and Lindholm 2021).

Risk management

We argue that people moved to the Åland Islands to create a new cultural niche – a niche of versatility. In this niche, as is evident in our data, typical agrarian activities of domestic animal husbandry as well as cereal cultivation have been implemented, which complemented the use of maritime resources and the involvement in long-distance trade. We argue that this niche adaptation was a method of risk management, reflecting the ability to adapt to unpredictable outcomes of everyday behaviours (Winterhalder, Lu, and Tucker 1999).

There are many studies on historic risk management, including those focusing on land use and subsistence strategies (e.g. Hatlestad, Wehlin, and Lindholm 2021; Marston 2011; Svensson 2019; Winterhalder, Lu, and Tucker 1999). Marston (2011) has pointed out that risk management is often based on diversification (see also Bajard et al. 2022); a diversification of crops in terms of spatiality as well as temporality can generate risk management. Similarly, we argue for a cultural niche of versatility, including cultivation of cereals (including *Hordeum*,[2] *Secale cereale*, *Avena*, and *Triticum*), grazing activities, utilization of a large variety of maritime resources, and involvement in trade.

The fact that Åland is small but still had available land likely contributed to the reason why people moved there in the first place, and it certainly made the versatile economic base much easier to apply, as all aspects of the niche were located in close proximity. The diversification can be seen not only in different types of activities but in different crops, in different types of domesticated and hunted animals and birds, and perhaps also in the spatial organization of settlements. It is clear that both maritime and terrestrial resources and habitats were used in parallel. In this context, it is notable that macrofossil analysis from the high-status settlement site of Kvarnbo Hall in the current study region suggests that animal husbandry did not take place at this site (Andersson 2017), yet we have indicators of grazing in our pollen signal. This leads us to wonder if the limited land was organized in a manner that cultivation took place in the lowlands (closer to the settlements), while the grazing activities occurred in the forested and hilly regions. This possible diversification strategy would indicate that people actively organized their landscape and aimed to maximize resource utilization by combining various available resources, which is another argument for a risk management approach by the Ålandic population.

It is well established that there was a demographic reorganization in northern Europe during the LIA, likely as an effect of the Late Antique Little Ice Age. It is possible that Åland saw a wave of "colonization" at that time as a course of action to construct a specific cultural niche to withstand the new climatic setting, indicating a conscious action of risk management. Notably, in northern Europe, there was a well-known wave of colonization of Atlantic islands during the Viking Age, which clearly points towards many different reasons for settling islands, as this colonization process happened during a period of more favourable climatic conditions (Hannon et al. 2005; Hannon and Bradshaw 2000; Johansen 1975; McGovern et al. 2006, 2007; McGuire 2006). Åland appears to have had enough available land to establish cultivation of cereals, among other things, while also offering areas usable for the grazing of domesticated animals. Simultaneously, there was easy access to marine resources, and the setting in the Baltic Sea provided possibilities to partake in the evolving trading systems of the period. Hence, the move to the Åland Islands appears in itself to have been a risk management strategy, resulting in a cultural niche based on a versatile economic base.

Another aspect indicating effective action towards societal resilience in agrarian practices is the choice of Cerealia. Both *Hordeum* and *Secale cereale* are cereals that tolerate a harsh climate and do not demand specific soil types. Archaeobotanical studies from Norway have recently shown that cultivation of *Secale cereale* appears to have had a key role in creating resilience during the cold Late Antique Little Ice Age climate (Westling et al. 2022), and this can be argued to be the case on Åland as well.

Starting from the middle of the tenth century, the land around Lake Lavsböle Träsk was once again used for intensified agriculture after a short period of weaker anthropogenic indications in the pollen signal. This then increased further in the medieval period, which could indicate a relatively large growth in population. Such population growth would suggest a society that was able to manage risks, as there is no evidence that people were noticeably affected by the medieval crises, including the Black Death, cattle panzootic, malnutrition, and economic downturn (Campbell 2016). Malnutrition was not a societal risk since food (cereals and meat, also dairy products) was produced, while the marine resources continued to be extensively used on Åland. Even if one aspect of the subsistence strategies failed (e.g. one year of bad cereal harvests), another aspect (e.g. marine resources) could be used more heavily instead. This flexibility could be argued to be an inherited risk management system from previous periods, when the risk consciousness of the Iron Age population was culturally transmitted to the medieval population.

An increase in population seems to be one possible explanation for why this region, starting in medieval times, once again witnessed intensified land use close to the lake. However, another possibility is that this shift could be the result of economic specialization among villages and farms, with households becoming more niche-focused towards one resource. In this scenario, one could speculate that inland regions were focused on producing Cerealia and animal products while coastal settlements utilized marine resources. This differentiation would have allowed farms and villages to be more widely spread out. Unfortunately, this scenario cannot be confirmed solely by the pollen record, and it must be verified or proven false using other types of archaeological data.

Conclusion

The archaeological data provide evidence that there was a rapid increase in the population on Åland in the beginning of the LIA. The region south of Lake Lavsböle Träsk became especially densely populated. The archaeobotanical data support the population increase, demonstrating an opening in the forest canopy with signs of grazing and cultivation of cereals. The use of pollen analysis, although biased towards terrestrial land use, has proven to be a valuable proxy to gain insights into land use during the Iron Age and medieval period, complementing archaeological data sets.

The focus of this study highlights the importance of agriculture on islands that generally have a strong maritime resource base. Both animal husbandry and the cultivation of cereals were part of the Iron Age economy, alongside trade and maritime resource utilization. The main cultivars were *Hordeum*-type and *Secale cereale*, two durable and easily grown cereals that were likely favoured due to the climatic disturbances resulting from the Late Antique Little Ice Age. The diverse economy indicates a cultural niche of versatility aimed to generate active risk management. In the latter part of prehistory, during the Viking Age, there is evidence of a demographic reorganization on Åland, as the intensity of land use decreased around Lake Lavsböle Träsk. During this period, there are still signs of anthropogenic land use in the region around Lavsböle Träsk, but the new phase of intense and more varied usage is once again visible starting from the medieval period. This points towards a continuous human presence in the region, yet a possible relocation or reorganization of settlements.

It is evident from our study that it was the increase in population during the LIA that led to the landscape in the region being changed by anthropogenic modification of the vegetational composition. After that, land use fluctuated, adaptations occurred, and settlements were reorganized, but it is possible to identify anthropogenic influences in the pollen signal and thus argue for the formation of active risk management on the islands through a cultural niche of versatility.

Notes

1. Unless stated otherwise, the current register of ancient sites on Åland (also digitally available at https://aland.maps.arcgis.com/apps/webappviewer/index.html?id=9d7cc07ab4004f0ca620038c4fd416ca) is the source for all the quantitative and chronological information in this article.
2. It is also worth pointing out that the *Hordeum* genus might include several species (e.g. Grabowski 2011).

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