Towards a refined understanding of the use of coastal zones in the Mesolithic: New investigations on human–environment interactions in Telemark, southeastern Norway

M. Wieckowska-Lüth [a], S. Solheim [b], A. Schülke [b], W. Kirleis [a]

[a] Institute for Prehistoric and Protohistoric Archaeology, University of Kiel, 24118 Kiel, Germany
[b] Museum of Cultural History, University of Oslo, 0130 Oslo, Norway

Abstract

The study of the effects of human presence on vegetation in the Mesolithic has been controversial. It is often assumed that hunter-gatherers did not change or affect their environment in a way that can be detected by means of pollen analysis. In this paper, we explore potential human impact on the vegetation during the Mesolithic by comparing pollen data from a high-resolution sediment core from Lake Skogstjern with archaeological data obtained through extensive excavation and survey in Bamble, in the county of Telemark, southeastern Norway. The aim of this interdisciplinary approach is to reach a better understanding of the development and use of Mesolithic woodlands with regard to the availability of different resources, but also to put the question of human impact on Mesolithic vegetation on the agenda. Mesolithic settlement in southeastern Norway was to a very large degree shore bound, and the pollen analysis from Lake Skogstjern, situated in the coastal hinterland, allows for new perspectives on and interpretations of the use of the coastal wider landscape.

Keywords: Pollen analysis, Mesolithic, settlement, southeastern Norway, coast, coastal hinterland

1. Introduction

During the past two decades, more than a hundred Stone Age sites have been excavated prior to highway and railway construction in southeastern Norway. Most of the sites were situated in former coastal areas along today's Oslo fjord (e.g., Jaksland and Persson, 2014; Melvold and Persson, 2014; Solheim and Damlien, 2013; Solheim (Ed.), 2017). These projects yielded large numbers of archaeological finds, which throw light on settlement in the coastal zone during the first part of the Holocene. Preservation of organic materials that could give insight into human–environment relations – such as bones, antler and macrofossils – is poor. The analysis of the Mesolithic sequence of a lake sediment core within the archaeological project E18 Rugtvedt-Dørdal is thus of special importance, as it illuminates vegetation development during this period and raises questions and possible answers about potential human–environment interactions.

The project E18 Rugtvedt-Dørdal was situated in the municipality of Bamble, in the county of Telemark. Thirty Mesolithic sites, ranging in date from c. 8700 to 4000 cal. BC, were excavated between 2013 and 2015, prior to the building of a new highway (Solheim (Ed.), 2017) (Fig. 1). The objective of the project was to explore the use of the coastal landscape in the Mesolithic (Schülke, 2017). As a part of the project, Kiel University carried out palynological investigations on a sediment core from Lake Skogstjern (Wieckowska-Lüth et al., 2017). This lake is situated only a few hundred metres from the project area and the Mesolithic sites (Fig. 1), and it is thus very suitable for a discussion of human–environment interactions. The lake deposits revealed detailed information on the entire vegetation history of the coastal area in Bamble; here we place special emphasis on the Mesolithic period, c. 9000–4000 cal. BC. This paper compares the palynological and archaeological results from the project and addresses the question of how Mesolithic coastal foragers may have used and altered the landscape in what was then a coastal area.

For Stone Age archaeology, the study of the effects of human presence on the vegetation has mainly focused on the Neolithic period and on topics related to the introduction of farming and animal husbandry (e.g., Feeser et al., 2012; Kramer et al., 2014; Whitehouse and Kirleis, 2014; Whitehouse et al., 2014). For the Mesolithic, however, the evaluation of pollen diagrams in terms of anthropogenic impact on the vegetation is a controversial issue (Bishop et al., 2015). The critical assessment by Behre (2007) shows that there is no hard evidence for anything like a “Mesolithic agriculture”. The possibility of Mesolithic populations having modified the woodland and the composition of naturally occurring species is mostly neglected (Behling and Street, 1999; Bos et al., 2005; Edwards, 2009; Hicks, 1993; Kolstrup, 1990; Kuneš et al., 2008; Poska et al., 2004). And even when the possibility is considered, it is often assumed that coastal foragers did not change or affect their environment in a way that can be detected by means of pollen analysis. Pollen-stratigraphical signs of what may represent anthropogenic activities within the Mesolithic forest are therefore often given little attention. Some palynological studies, however, are concerned with the recognition of human impact in early and mid-Holocene woodlands. Based upon pollen-stratigraphical evidence, they show temporary phases of small-scale forest openings. These woodland disturbances are indicated by short-term fluctuations in arboreal pollen, abrupt changes in tree pollen curves, and increases in palynological diversity within the light-demanding and/or nitrophilous taxa (Bishop et al., 2015; Bos et al., 2005; Boyd and Dickson, 1986; Brown, 1997; Edwards, 2004; Gumiński and Michniewicz, 2002; Hörnberg et al., 2005; Huntley, 1993; Iversen, 1973; Kuneš et al., 2008; Latalowa, 1992; Poska et al., 2004; Wacnik, 2005). Furthermore, the presence of microscopic charcoal particles (Edwards, 1990; Edwards et al., 2007; Innes et al., 2010; Mason, 2000; Mighall et al., 2008; Wieckowska et al., 2012) and the occurrence of certain non-pollen-palynomorphs (NPP) indicative of grazing, local burning, soil erosion or accumulation of dead organic material provide additional evidence of disturbance within the vegetation (Edwards, 1990; Innes et al., 2010; Mason, 2000; Mighall et al., 2008; Wieckowska et al., 2012).

Plants played an important role in the subsistence of Mesolithic people because they provided food, construction materials for dwellings, fuel for cooking and heating, fibres for clothing and organic material for tools and other objects, to mention just a few. We therefore assume that, starting as early as the early Holocene, environmental and climatic changes were not the only factors that influenced vegetation composition and facilitated the presence of certain plant resources – and that thus made people adapt or modify their land-use strategies. In addition, intentional or unintentional activities of coastal foragers and their impact on the natural abundance and distribution of certain plant species should be considered when discussing Mesolithic vegetation dynamics. The utilisation of a permanent or a seasonally but recurrently used Mesolithic dwelling site would certainly have influenced the surrounding vegetation. For example, the use of the adjacent woodlands to collect timber as construction material and wood for tool production and fuel would have further disturbed the natural vegetation succession (Klooß, 2015). Furthermore, refuse deposition created favourable conditions for the flourishing and spreading of nitrophilous herbs and grasses, as well as light-demanding shrubs. Thus, the question is not ‘Did coastal foragers affect the environment?’, but ‘How and on what scale?’ (Behre, 1981; Dincauze, 2000) – and how we can trace these minor interferences during the early Holocene, before the onset of farming.

2. Material and methods

2.1. Archaeological data

The municipality of Bamble is today part of the coastal Skagerrak region (Puschmann, 2005), which is characterised by islands, skerries and fjords stretching from the coast to areas inland. The geological development of the Oslo fjord region has resulted in a special situation for Stone Age archaeology. After the retreat of the Scandinavian Ice Sheet, c. 12,500 cal. BP, there has been continuous land uplift, and the glacio-isostatic rebound has caused dramatic changes in the region's landscape (Bergstrøm, 1999; Sørensen et al., 2014). Consequently, Mesolithic sites are located at different heights above the present-day sea level (Fig. 2). The shoreline displacement curves developed by geologists are used by archaeologists to a) date Mesolithic coastal sites (a process known as shoreline dating) and b) reconstruct the coastal landscape and shoreline. The combination of shoreline displacement curves and technological and typological studies of the sites' lithic assemblages, as well as ^{14}C dates, makes it possible to establish a relative site chronology and assign Mesolithic sites to different archaeological phases, provided that the site in question was situated close to the shoreline at the time (e.g. Glørstad, 2004: 97-98; Bjerck, 2008: 68; Breivik et al., 2017: 11).

Studies show that most of the known Mesolithic sites in the Oslo fjord region were originally situated in sheltered positions close to the contemporary shoreline. The close correlation between ^{14}C-dated archaeological contexts and the shoreline displacement curves further indicates that Mesolithic people moved their sites according to changing sea levels (Breivik et al., 2017). This reflects the importance of the coast as a dwelling and resource zone for Mesolithic groups. However, as Berg-Hansen (2009) noted, the preponderance of coastal sites may be the result of bias due to surveying procedures in today's forest zones, which can reinforce the coastal location of Mesolithic sites. Therefore, our knowledge of the possible use of the direct coastal hinterland is thus far limited. This is also the case for Bamble.

For a long time, only one Mesolithic site had been excavated in Bamble (Mikkelsen, 1989; Odgaard, 1993). During the past decade, more than 200 sites dating to the Mesolithic and the Neolithic have been documented through test pitting (50 × 50 cm) in this area as part of different construction projects (Fig. 2). Furthermore, 30 Mesolithic sites have been excavated as part of the E18 Rugtvedt–Dørdal project (2013–2015), all of them former coastal sites (Table 1). Within the area surveyed for this project, the density of sites is 14 sites per km^2. Most of the surveyed sites are located within c. 5 km of the shore of Lake Skogstjern, while the excavated sites are situated at a distance of between 1 and 10 km from this lake, with the majority between 1 and 3.5 km (Table 1). The sites that are located within a kilometre of the lakeshore most likely represent Early Mesolithic coastal sites dating to the period 9000–8000 cal. BC, that is, prior to the isolation of the lake from the former fjord. No Mesolithic sites that are concurrent with or younger than (i.e., situated lower in the landscape) the isolation of the lake have been documented within the pollen catchment area of Lake Skogtjern (a radius of approximately 800 m from the lake margins; see below).

It should be mentioned that no archaeological surveys were carried out directly on the shore of Lake Skogstjern, as the building of the new highway was not going to impact the lakeshore. This may represent a source of bias in our data. Sites relevant for a discussion on human impact on the vegetation as documented by the pollen analysis are concurrent with and younger than the isolation of the lake at c. 8000 cal. BC, corresponding to the Middle and Late Mesolithic periods. The distribution of Mesolithic sites can be regarded as representative for the use of the coastal zone during this time span.

The land uplift has conferred several advantages for identifying and accessing Mesolithic sites. As sites from the entire Mesolithic are situated in today’s forested areas, relatively high above sea level, they are often undisturbed by modern activity. However, there are also some disadvantages. Conditions for the preservation of organic material are poor. The sites are dominated by lithic finds and structures, such as fireplaces and cooking pits (Solheim (Ed.), 2017). Organic materials, such as bones, fibres or macrofossils, which can give insight into human–environment relations and the use of natural resources, are only rarely found (e.g., Mansrud, 2014; Persson, 2014a).

2.2. Pollen analysis

The small-sized Lake Skogstjern has a surface area of about 2.6 ha and measures c. 130 m × 270 m, and it is currently situated at 57.2 m a.s.l. (Fig. 3). The lake was connected to the sea in the Late Glacial and Early Holocene, when it constituted the inner part of a small fjord (Høeg, 1982, 1980). Today, its outflow to the southeast reaches the modern Åbyfjorden after 2.4 km. Alkaline-rich cambro-silurian bedrock characterises the surrounding landscape. The typical soil type is podzol (Låg and Norges Landbrukshøgskole, 1983). The area adjacent to the lake is dominated by forest. Nearly one third of the shoreline currently consists of farmland on the more gentle slopes. Based on its size, we can calculate that the deposits of Lake Skogstjern mainly reflect the vegetation of an area of approximately 800 m around the lakeshore (Fig. 3) – that is, the signal of extra-local vegetation (Sugita, 1994, 1998).

In January 2013, a sediment core of 7 m was obtained from the lake (Persson, 2014). The sediment consisted of fine detritus gyttja in the upper part and marine deposits below c. 403.4 cm. To gain high-resolution data for certain archaeological periods, the core was sampled at intervals of 1 cm (from 267 to 322 cm depth), respectively, 2 cm (from 322 to 418 cm depth) throughout the Mesolithic section. Sample preparation, data processing and dating are described in Wieckowska et al. (2017). For the period between c. 8500 and 4000 cal. BC, a record with a temporal resolution of c. 12–38 yr/cm is available for Lake Skogstjern. The Mesolithic pollen record consists of 103 pollen spectra. Based on major changes in pollen proportions, four main Mesolithic pollen assemblage zones (MPAZ A–D) were distinguished in the pollen diagram. These zones were further subdivided based on minor changes in the pollen assemblages (MPAZ B1/B2, C1/C2/C3 and D1/D2) (Fig. 4).

3. Results and Interpretation

3.1. The transition from the Early to the Middle Mesolithic, 8500–8000 cal. BC: A coastal environment with archaeological sites in an outer archipelago

From 8500 cal. BC onwards, the coastline in the Bamble area changed rapidly, with a regression rate of c. 7 cm/year (Sørensen et al., 2016). The area was characterised by an outer archipelago with only a few small islands located outside the mainland (Fig. 5). The last part of the Early Mesolithic (c. 8700–8300 cal. BC) is well documented archaeologically, with 29 surveyed and 11 excavated sites located between 110 m and 75 m a.s.l. (cf. Fig. 2). These sites were in use before Lake Skogstjern became isolated from the sea, and there is an increase in the number of sites at around the time of the lake’s isolation. The excavated sites dated to after 8200–8000 cal. BC show greater variation in size and lay-out than those from the preceding Early Mesolithic period. They consist of one or several concentrations of lithic materials, which also contain raw materials of local origin. This may indicate greater familiarity with the resources in the local landscape than in the Early Mesolithic phase (Damlien, 2016; Damlien and Solheim, 2017).

The landscape during the transition from the Early to the Middle Mesolithic is characterised in the pollen record by the deciduous tree taxa *Betula* and *Corylus* (MPAZ A) (Fig. 4). The simultaneous high amounts of *Pinus* arise from a possible over-representation of pine pollen, which may be due to a high degree of long-distance transport of pollen within a more or less open coastal vegetation (Wieckowska-Lüth et al., 2017). Such a relatively open vegetation structure is reflected in a fairly high abundance of shrubs, dwarf-shrubs and other non-arboreal pollen from *Hippophaë*, *Juniperus*, *Salix* , *Vaccinium*-type, *Calluna*, Poaceae and Chenopodiaceae, the latter probably mainly reflecting halophilous vegetation, as many representatives of this family grow as pioneers on the seashore (Danielsen, 1970).

By the uppermost part of this zone, visibly elevated proportions of microscopic charcoal particles appear between c. 8100 and 8020 cal. BC, which may indicate local burning. This is accompanied by distinct rises in Poaceae and several herbs (*Artemisia*, Chenopodiaceae and Liguliflorae), which show the presence of some disturbed ground. Contemporaneously, the occurrence of fungal chlamydospores of *Glomus* sp. (HdV-207) points to erosion of the surrounding soils (van Geel et al., 2003). At the same time, there is a decrease in the amount of arboreal pollen, whereas light-demanding shrubs such as *Juniperus*, *Sorbus*/*Rubus*-type and *Salix* increase slightly. These changes in pollen taxa composition may have been induced by burning, as evidenced by the presence of micro-charcoal within the sediment. However, it is virtually impossible to assess unambiguously whether the charcoal dust represents natural or anthropogenic fire events. Natural woodland fires can certainly happen, most often ignited by lightning strikes (Moore, 1996, 2000), although this is an infrequent occurrence (Chandler et al., 1983). However, there is also a debate about deliberate firing of vegetation during the Mesolithic (e.g., Blackford et al., 2006; Bos and Urz, 2003; Innes and Simmons, 1988, 2000; Mellars, 1976; Moore, 2000). It is at least conceivable that burning may have been used to maintain or extend the openness of the seashore vegetation (cf. Edwards et al., 2009; Mellars and Dark, 1998). The increased microscopic charcoal record may also be associated with domestic fires from hearths (Bennett et al., 1990; Edwards, 1990), although these are likely to have been on a much smaller scale (Ryan and Blackford, 2010).

3.2 The Middle Mesolithic, c. 8000–6800 cal. BC: Light woodland with the use of varied locations

During this period, the Bamble archipelago became less exposed. The islands along the outer coast grew larger due to regression, and the amount of sheltered water and harbours increased. After 8000 cal. BC, the number of known sites in Bamble increased, with 81 sites that are shoreline dated to the time span 8000–6800 cal. BC. Six sites were excavated within the E18 Rugtvedt-Dørdal project (Table 1; Fig. 5). The sites are located in a variety of topographical settings, along sounds, in small bays and at the open coast on the mainland, but also on islands. The different settings may indicate that the sites were used for different purposes and for specialised activities, such as fishing (Persson, 2014a), hunting sea mammals (Havstein, 2017), dwelling (Solheim and Olsen, 2013) or storage of raw materials (Koxvold, 2013). This phase concurs with distinct cultural changes in southeastern Norway in general, with a) a shift in lithic technology, most likely reflecting groups migrating into the region (Damlien, 2016), and b) a more differentiated use of the landscape, including a shift from a highly mobile society in the Early Mesolithic to a (semi-)sedentary system in the Middle Mesolithic (Solheim, 2013).

The beginning of the Middle Mesolithic is characterised in the pollen record by an abrupt rise in the warmth-demanding *Corylus* (MPAZ B). This, together with a distinct increase in the light-dependent *Betula,* reflects the expansion of open, hazel-rich birch forests. At the same time, slightly elevated values of the thermophilous forest elements *Ulmus* and *Quercus* show that these taxa were also present, but that they played a minor role in the forest inventory. Another characteristic element occurring at this stage is the expansion of *Alnus* in wet areas around the lake. At c. 8000 cal. BC, the change from marine to gyttja sediments marks the isolation of the basin from the sea (Wieckowska-Lüth et al., 2017).

The time period between c. 8000 and 7450 cal. BC (Subzone B1) is marked by increases in the pollen frequencies or, respectively, the occurrence of some heliophilous shrubs and dwarf-shrubs, such as *Salix*, *Sorbus/Rubus*-type, *Viburnum opulus*-type, *Juniperus*, *Calluna* and *Vaccinium*-type, which, together with relatively high values of Poaceae, reflect openings in the forest canopy. This change is coupled with an expansion of herbaceous taxa, particularly *Rumex acetosa*-type and *Artemisia*, but pollen of other ruderals, such as *Urtica*, Caryophyllaceae, Chenopodiaceae, *Senecio*-type or *Geum*-type, also occurs occasionally. This palynological record may refer to natural disturbances, such as open areas along the lake shore, precipices or rock outcrops, talus formations and landslides where sufficient light is present, enabling these plants to grow. On the other hand, these pollen signals of the representatives of disturbed vegetation appear together with elevated levels of microscopic charcoal particles, albeit that the latter were not recorded continuously throughout this phase. The presence of micro-charcoal remains is followed by the presence of *Calluna*, which is known to have a positive association with fire (Blackford et al., 2006; Rodwell, 1991), as well as by *Pteridium,* a common fire-adapted fern (Bińka and Nitychoruk, 2013; Tinner et al., 2000). During this time, *Corylus* seems to have been influenced by fire, as its highest abundance correlates positively with the increase in micro-charcoal, whereas the rises in *Betula* pollen usually follow the declines in hazel, pointing to phases of forest succession. The increase in charcoal dust could be a result of natural burning, but the pollen stratigraphical evidence shows deciduous tree cover dominated by birch and hazel stands. *Betula* and *Corylus* do not burn as readily as conifers and their litter (Ryan and Blackford, 2010); therefore natural fires in such environments appear unlikely (Edlin, 1970; Rackham, 1986). Hence, anthropogenically induced small-scale openings in the woodland resulting from the use of fire also have to be taken into consideration. Whatever the case, a possible occupation of the lakeshore by coastal foragers is indicated by the evidence of *Artemisia*, Chenopodiaceae and *Urtica*, which are primary nitrophilous species that occur on highly disturbed shorelines/riverbanks and that may also be associated with nitrogen-rich areas around dwellings (Behre, 1981). Elevated levels of Cyperaceae also demonstrate the existence of open ground close to the lake basin. At the same time, the occurrence of *Rumex acetosa*-type, *Senecio*-type, Caryophyllaceae and *Geum*-type may represent the floral signal for open ground disturbed by trampling. A find of a fungal spore of *Sordaria* sp. (HdV-55A) could point to the presence of animal dung. However, although the growth of Sordariaceae is encouraged by dung, they can also occur on a range of other organic substrates (van Geel and Aptroot, 2006), and in those situations they are indicative of increased availability of dead and decaying wood and plant matter. Moreover, ascospores of *Diporotheca webbiae* (HdV-143) were also identified. The presence of this taxon in lacustrine sediments suggests that ground disturbance in wet *Alnus* carrs (Hawksworth et al., 2016), and subsequent soil erosion, may have been decisive for their input to the lake (Hillbrand et al., 2012).

The time span between 7450 and 6840 cal. BC (Subzone B2) is distinguished by a visible reduction in the non-arboreal pollen taxa *Calluna*, Poaceae and Cyperaceae and in shrubs, such as *Salix*, *Viburnum opulus*-type and *Corylus* – although a distinct hazel peak appears once more in the lower part of this phase. This rise in *Corylus* between 7370 and 7220 cal. BC follows the increases in the quantity of microscopic charcoal particles, and may relate to regenerating woodland after a phase of increased fire activity. However, the general decline in the light-demanding shrubs *Corylus*, *Viburnum opulus*-type and *Salix*, together with the presence of other open-land indicators, could be due to smaller-scale forest disturbances compared with the previous period. Nevertheless, even though the values of Poaceae have diminished, they remain at a more or less constant level, showing that there were still small gaps in the forest canopy.

The contemporaneous presence of *Humulus*/*Cannabis*-type, representing in all probability the creeper *Humulus lupulus*, suggests that there were also some gaps in the tree canopy of the wetland forests, as wild hop occurs preferentially at nitrogen-rich sites with higher soil moisture, at forest margins or in shrubbery (Düll and Kutzelnigg, 2005). However, elevated levels of microscopic charcoal particles were recorded somewhat later, between c. 7140 and 6910 cal. BC. These are followed by increases in *Calluna*, pointing to successive expansion of heath on fire-disturbed sites. At the same time, the more frequent occurrence of the fungus *Diporotheca webbiae* in the sediment indicates increased erosional input to the lake, probably due to soil disturbances along the basin (Hillbrand et al., 2012). Therefore, it seems possible that the micro-charcoal recorded originates from domestic fires within campsites at the lakeshore, which were recurrently used. At the same time, the occurrence of fungal spores of *Coniochaeta xylariispora* (HdV-6) indicates an increased amount of dead wood (van Geel, 1978) or the presence of game dung (Blackford et al., 1996; Ellis and Ellis, 1988) in the lakeshore environment.

3.3 The late Middle Mesolithic to the Late Mesolithic, c. 6800–5500 cal. BC: Increasingly dense woodland and varied settlement along the coast

The time between 6800 and 5600 cal. BC was characterised by a relatively slow regression and minor changes in the coastal topography. This period is less known archaeologically compared with the time periods before and after, as only 26 sites are documented for a time span of 1200 years, and only one of these has been excavated (Table 2). Also, in southeastern Norway in general the late Middle Mesolithic phase is rather poorly documented (Damlien, 2013).

This stage is characterised by a distinct rise in *Ulmus* (MPAZ C), demonstrating a gradual transition from open birch forest to a mixed wooded landscape. During this time, *Tilia* also arrived in the area, but it remained insignificant initially (Wieckowska-Lüth et al., 2017). In general, the abundance of *Corylus* increases again in this phase, suggesting that the growth of hazel was somehow promoted (Subzones C1/C3).

During this time (MPAZ C), the values of micro-charcoal reach higher frequencies in some levels, as in the previous stage, but in some levels there are no records. In one case, the occurrence of *Gelasinospora* (HdV-1), a fungus which prefers dry conditions and layers with charred material (van Geel and Aptroot, 2006), indicates that burning was local. Besides, the values of *Calluna* show several small increases, nearly always matching the elevated amounts of *Pteridium*. In most cases, both taxa seem to follow the peaks in micro-charcoal. On the other hand, some of the steepest *Corylus* increases (358, 350, 338, 326 cm) correspond to the highest records of microscopic charcoal particles. This indicates that the spread of hazel shrubs was probably promoted through burning. Furthermore, this phase displays a comparatively higher abundance of fungal spores, including *Cercophora* sp. (HdV-112), *Sordari*a sp. (HdV-55A) and *Coniochaeta xylariispora,* as potential indicators of animal dung. *Cercophora*-types are predominantly coprophilous, but some can also occur on decaying wood, on culms and on other herbaceous stems and leaves (Lundquist, 1972). *Sordaria* and *Coniochaeta* species are encouraged by dung, but they can also occur on a range of other organic substrates (Ellis and Ellis, 1988; Lundqvist, 1972; Ryan and Blackford,

2010). Other fungal types, such as *Ustulina deusta* (HdV-44), and the soil erosion indicators *Diporotheca webbiae* and *Glomus* sp., also occur sporadically. Innes et al. (2006) have suggested that *Ustulina deusta* (=*Kretzschmaria deusta*), a parasite causing soft-rot of wood (van Geel and Aptroot, 2006), may indicate the presence of wounded and dying deciduous trees. On balance, the increased component of fungal spores may hint at temporary concentrations of game in the surroundings of the lake. Disturbed areas within the forest referring to grazing animals may be attested to by the occurrence of *Rumex acetosa*-type. As highlighted in several studies dealing with human impact on the Mesolithic environment (Blackford et al., 2006; Edwards, 2009; Innes et al., 2010; Mellars, 1975, 1976; Moore, 2000; Ryan and Blackford, 2010; Zvelebil, 1994), deliberate burning of vegetation to create more productive habitats for game animals and thereby improve the chances of hunting success can, in principal, be taken into consideration to explain this phenomenon.
Over the time span c. 6400–6150 cal. BC (Subzone C2), two sudden and distinct declines in the frost-sensitive *Corylus* are recorded, whereas the low-temperature-adapted *Juniperus* increases, pointing to the 8.2 ka cooling event (e.g., Alley et al., 1997; Antonsson and Seppä, 2007; Seppä et al., 2005; Wieckowska-Lüth et al., 2017). At the same time, the visible reduction in pollen of some representatives of disturbed forest vegetation, such as *Sorbus*/*Rubus*-type, *Salix*, *Calluna* and *Pteridium*, reflects fewer gaps in the forest canopy. The amounts of microscopic charcoal particles, on the other hand, remain at least in part relatively high, and may reflect the input of micro-charcoal fragments from domestic fires into the lake sediment. Slightly increased frequencies of *Rumex acetosa*-type, *Artemisia*, Cyperaceae and *Humulus*/*Cannabis*-type, together with conspicuously high values of Poaceae over a longer time period, point to open areas that may relate to the existence of campsites at the lakeshore. In parallel, the presence of fungal spores of *Coniochaeta xylariispora* and *Diporotheca webbiae* suggests the presence of both decaying organic material and disturbed ground around the water basin. Overall, the pollen record suggests that the local environment was intensively disturbed, whereas the woodland surrounding it remained largely unaffected by anthropogenic activities during that time.

3.4 The final part of the Late Mesolithic c. 5600–4000 cal. BC: Dense and diverse forest landscape with increased sedentism and varied site locations

During the last part of the Late Mesolithic, Bamble appeared as a sheltered archipelago with several inlets, sheltered water and straits. Sites were situated at the mouth of a larger fjord system reaching farther inland, especially close to narrow sounds and straits (Fig. 6). This period, particularly c. 5600–5000 cal. BC, is well documented, with 33 surveyed and 10 excavated sites (Table 1). The number of sites is, however, relatively smaller than, for example, in the Middle Mesolithic period. In this period the sites also showed varied locations, and intra-site organisation and lithic assemblages reflects different use, for example, production of axes or dwelling sites (Solheim (Ed.), 2017). Some of them are large in size, most likely reflecting occupation over a longer period, within a more stable settlement system (Glørstad, 2010). The period was characterised by extensive use of local raw materials in addition to flint for making stone tools, especially axes/adzes.

According to the pollen record, a new type of forest characterises this stage (MPAZ D). At the beginning of this period, there is a strong decrease in the pollen values of *Corylus*, along with parallel rapid increases in *Tilia* and *Quercus* (Subzone D1). The insect-pollinated *Tilia* does not disperse its pollen as effectively as do other forest trees, and it is therefore often underestimated as a component of the forest (Prøsch-Danielsen, 1996). Hence, from this time onwards, lime was probably one of the major tree taxa in the catchment of the lake (Wieckowska-Lüth et al., 2017). Nevertheless, recurrent, strongly fluctuating values for lime indicate repetitive gaps in the forest canopy. These declines in the quantities of *Tilia* are often succeeded by increased proportions of the light-demanding *Corylus* and *Juniperus*. These shrubs, in turn, are coincident with the marked increases in the open-land indicator *Calluna*. Conversely, frequent phases of woodland regeneration are demonstrated by the strongly oscillating curve of *Betula*, reflecting its nature as pioneer tree that expands in open areas. Such locations are furthermore reflected in the pollen record by the repetitive small peaks of pollen of several ruderals, such as *Rumex acetosa*-type, *Artemisia*, Caryophyllaceae, Chenopodiaceae, *Urtica*, *Trifolium repens*-type, *Senecio*-type, Liguliflorae, *Polygonum aviculare*-type, *Potentilla*-type, *Geum*-type, *Thalictrum* and Poaceae. Moreover, the regular occurrence of *Humulus*/*Cannabis*-type may point to frequent, small-scale open locations along the lake. Synchronously, finds of fungal spores of *Glomus* sp. and *Diporotheca webbiae* can be linked to increased erosional input to the lake due to human activities at its shore. Other representatives of fungi indicative of accumulations of dead organic plant material, such as *Cercophora* sp., *Coniochaeta xylariispora* and *Ustulina deusta*, are most abundant in the older part of this period (Subzone D1, 5550–5000 cal. BC), as is the strongest evidence of microscopic charcoal particles. In contrast, the decline in the frequency of *Pteridium* (Subzone D2) over the further course of this period may be associated with reduced fire activity, as demonstrated by the visibly diminished amounts of charcoal dust from c. 4990 cal. BC onward.

4. Discussion

4.1. A comparison of the pollen analytical and archaeological results in the Bamble region

Pollen analysis has long been applied in Stone Age archaeology in southeastern Norway. The focus of research has been on the reconstruction of sea-level curves or on the vegetation history of shorter periods by the combining of several pollen profiles (e.g., Hafsten, 1957; Mikkelsen, 1989; Sørensen et al., 2014; Welinder, 1981). The recent analysis of the sediments of Lake Skogstjern provides a unique overview of the vegetation history of the Mesolithic period in southeastern Norway. The results open up new perspectives on the interpretation of the archaeological record, which, up till now, has been generally characterised by a lack of organic environmental data. The interaction between people and the surrounding vegetation has thus been little explored in this region. Two aspects that can be discussed in connection with the pollen data from Lake Skogstjern will be emphasized in what follows: First, the pollen data can be used to reconstruct changes in local vegetation cover and possible uses of available plant resources throughout the Mesolithic. Second, the analysis of a lake situated in the coastal zone, but farther away from the shoreline than the many Mesolithic coastal sites, can contribute to a better understanding of a varied use of the wider coastal landscape, and to aspects of mobility, complexity of use of an area, and aspects of social organisation (e.g., Binford, 1980). Both aspects contribute to a broader understanding of Mesolithic coastal communities in terms of environment and spatial organisation. The analysis of the lake sediments, which reflect local development, will be discussed below in relation to the Mesolithic archaeological data from the Bamble area.

Lake Skogstjern became isolated from the sea at c. 8100–8000 cal. BC, at the beginning of the Middle Mesolithic. Due to the constant regression in the Oslo fjord region, the lake's local topography and surroundings gradually changed. Ever since the lake became isolated, it has been situated on the mainland, at increasing distance from the sea, and with its narrow outflow growing in length. These changes had an impact on the accessibility of the lake, because it was changing from a saltwater lagoon to a sheltered, coast-near-freshwater reservoir that possibly was accessible from the sea by boat through the narrow passage of the outflow. The lake and its surroundings provided faunal and vegetational resources different to those of the seashore, including water birds and eggs, rhizomes, tubers and seeds of certain water plants, fruits, nuts, acorns, branches and timber of specific wood species, whereas the coast would have provided marine mammals, water birds, marine fish and shellfish. In addition, the lake may have attracted smaller animals and big game for drinking, and thus became a focal point for the hunting of prey for humans.

The pollen record suggests that people frequented the area around Lake Skogstjern at several stages during the Mesolithic. This indicates the potential importance of the direct coastal hinterland as an economic zone or dwelling area, and points to people's physical movement within the coastal landscape. The question is whether the use of the lakeside represents shorter visits for economic or other reasons, or whether human activity as represented in the pollen record may hint at more stable settlement along the lake. Movement between the lake and the outer coast must be described as short-distance movements, as the distance to the seashore was less than a kilometre.

For the centuries between c. 8000 and 6800 cal. BC, a recurrent use of the lakeside is suggested in the pollen record. In addition, the archaeological record indicates that there were high levels of activity in the area during this time span. The pollen data show signs of anthropogenic impact in the form of trampling and small-scale openings caused by the use of fire. The accumulation of pollen of representatives of disturbed vegetation and the highest relative signal of microscopic charcoal (MPAZ B1) around the time of the isolation of the lake (c. 8100–7640 cal. BC) correspond well with the archaeological evidence of human presence in the nearby area, documented by four excavated sites and 50 surveyed sites that most likely date to the period c. 8000–7600 cal. BC, that is, the first part of the Middle Mesolithic (Table 1).

This parallels the general picture of the Middle Mesolithic in the Oslo fjord region, which is quite well represented in the archaeological record up to c. 7000 cal. BC (Damlien, 2013). A general feature in Bamble, but also in the wider region, is that the sites are different in character and location, indicating a specialised utilisation of different places in the coastal landscape, including at sheltered bays, alongside sounds and on outer islands (Solheim, 2013). People seem to have used the area dynamically. The repeated use of the lake in this period strongly indicates that the coastal hinterland was attractive. In the further course of time, however, the archaeological record shows a decline in number of sites, while the pollen profile signals domestic fires and recurrent use of the lakeside between c. 7450 and 6840 cal. BC. Here, the pollen profile may point to a bias in the archaeological data. Further studies may show whether the decline that is generally observed in the Oslo fjord region represents the factual situation at that time. Warren et al. (2014) state that possible Mesolithic woodland disturbance is evident in 30–40 % of pollen records examined in Ireland and that such disturbance is evidenced frequently, even in pollen diagrams from areas where Mesolithic activity is not well recorded archaeologically.

Furthermore, small-scale openings around the lake at different stages of the late Middle Mesolithic and first part of the Late Mesolithic (MPAZ C) can be observed, together with an increased proportion of charcoal dust. During these phases, hazel seems to have been promoted by burning in particular. Hazel may have been an important raw material, not only as fire-wood, but also for the setting up of smaller structures, such as shelters, fences, walls, baskets or fish traps (Klooß, 2015; Regnell, 2012; Wilkinson and Vedmore, 2001). Manipulation of hazel shrubs by burning may also have been undertaken to further increase the production of hazelnuts (Bishop et al., 2013; Blackford et al., 2006; Holst, 2010; Huntley, 1993; Warren et al., 2014). Thus, the rise in micro-charcoal, along with fluctuations in the ratio of arboreal to non-arboreal pollen, may reflect small-scale openings created for improving the supply of useful plants, for attracting hunting prey or for the use of the lake area for extracting raw materials (Rowley-Conwy and Layton, 2011). These signs of human impact indicate that Lake Skogstjern was a frequented and utilised zone, possibly with deliberate manipulation of the vegetation for resource purposes. Manipulation of vegetation is an indicator of people's active engagement with an area, which has implications for the temporal factor of planning (Innes et al., 2013; Mason, 2000). Other signs of sedentary settlement, for example, the site Hovland 3 in Vestfold county, are recorded in the archaeological data from the Middle Mesolithic onwards (Solheim and Olsen, 2013). These intentional vegetation changes by humans bring a new dimension into our understanding of these Mesolithic groups.

4.2. The final part of the Late Mesolithic (c. 5500–4000 cal. BC): High human impact at Lake Skogstjern

In this section we will take a closer look at the final part of the Late Mesolithic, the time between 5500 and 4000 cal. BC (MPAZ D). At this stage, the lake was situated approximately 500–600 metres away from the contemporary coastline. It appears that small groups of humans utilised the area around the lake continuously during this time period. Repetitive gaps in the forest canopy are indicated by repeated fluctuations in *Tilia*, which alternate with rising pollen assemblages of the light-demanding *Corylus* and *Juniperus*, possibly due to human manipulation. Potential human activity is further indicated in the first one third of the zone (c. 5560–5000 cal. BC) by significant traces of fire activities, reflected by elevated amounts of microscopic charcoal and high values of *Pteridium*. The increase in diversity of herbaceous

taxa and recurring increases of pollen of ruderals suggest the frequent occurrence of small-scale open locations along the lakeshore, which can be interpreted as human-made.
It has been pointed out that there is no explicit signature for distinguishing anthropogenic woodland management in pollen diagrams (Bishop et al., 2015). One form of anthropogenic interference that is expected to have occurred in the natural environment in southeastern Norway during the early Holocene is small-scale interference in woodlands in order to promote particular plant composition (cf. Warren et al., 2014). Niche construction has been widely discussed among archaeologists, and although in many instances the discussion mainly relates to farming communities, it is reasonable to assume that hunter-gatherers also affected and changed the landscape they lived in (Bishop et al., 2015; Edwards, 2009). One example is the burning of vegetation to encourage growth of certain vegetation species, such as hazel, or to encourage growth of ground vegetation, such as herbs and grasses, to attract animals (Rowley-Conwy and Layton, 2011).
As the archaeological data indicate, this is a time of intense human activity in the Bamble area. Ten sites dating to c. 6000–4000 cal. BC were excavated as part of the E18 Rugtvedt–Dørdal project, of which seven can be dated between c. 5500 and 5000 cal. BC (cf. Table 1) (Solheim (Ed.), 2017). In the Stokke/Polland area, about 3.5 km east of Lake Skogstjern, there was abundant activity during the Late Mesolithic, documented both by excavated and by surveyed sites (Fig. 6). This seems to correspond well to repetitive gaps in the forest canopy and significant traces of fire activity evidenced in the pollen record.
It is well documented that hunter-gatherers use their territories dynamically (Grøn, 2005), and we consider it highly likely that the hinterland located directly behind the contemporary shoreline was used during the Mesolithic. Possible explanations for the openings and changes in vegetation are landscape burning, which increased the diversity in vegetation and furthered the economic significance of particular plants (Grøn, 2012). Coppicing, which is a well-known practice among historical hunter-gatherers, is also a possible explanation (Bishop et al., 2015; Warren et al., 2014).

4.3 Linking the material culture with the environment in the Late Mesolithic

After 5600 cal. BC, co-occurring with the frequent utilisation of Lake Skogstjern as demonstrated by the palynological data, we can discern important changes in the archaeological record in the region that coincide with the introduction of a new axe type, the Nøstvet axe, which seems to go hand in hand with a shift in lithic tool technology (e.g., Eigeland, 2015; Reitan, 2016). This is well documented at the excavated sites in Bamble, where the production of Nøstvet axes using local raw materials is evidenced 5400–5000 cal. BC (Fig. 7; see also Eigeland and Fossum, 2014).

The shift in material culture may possibly provide us with some clues to the types of human activity that took place around Lake Skogstjern. The sites containing waste from axe production are concurrent with or slightly post-date important changes in the forest composition involving a rise in *Quercus*, *Fraxinus* and *Tilia*, seen both in the Skogstjern diagram (cf. Fig. 4), but also in southeastern Norway in general from c. 5700–5500 cal. BC (Høeg, 1982; Sørensen, 1996). Given the concurrent rise of *Tilia* and the introduction of the Nøstvet axe, an interesting question in this specific case is whether the repetitive gaps in the forest canopy and the traces of fire activities can be linked to the use of *Tilia* as raw material for wooden implements. Lime is known to be soft and easily workable, and it has a low net weight. It absorbs little water and floats well (Nedkvitne and Gjerdåker, 1997; cf. Jaksland, 2005). This makes it a good raw material for dugout canoes, which is illustrated by finds of log boats from southern Scandinavia, where lime is the preferred wood type (Christensen, 1997; Rowley-Conwy, 2017). Further, lime bast is also an important raw material for the production of rope and fishing implements (Nedkvitne and Gjerdåker, 1997).

The use of the axe has been discussed repeatedly (e.g., Glørstad, 2010; Jaksland, 2005; Østmo, 1995). Jaksland (2005) and others have interpreted the Nøstvet axe as a woodworking tool. The geographical distribution of this axe type along the coast and large water systems has led researchers to suggest that it had a function related to coastal life, and more specifically to making log watercraft. Glørstad (2010, 2011) has recently elaborated on the geographical distribution of *Tilia* and Nøstvet axes and demonstrates a connection between the northern limit of lime in the Atlantic period and the distribution of these axes. This general observation is supported by the data produced in our study, which demonstrate 1) a start date for of Nøstvet axe production at excavated sites in Bamble and neighbouring regions of c. 5500 cal. BC (Fig. 7), and 2) a concurrence between the increase in the lime curve for the catchment area of Lake Skogstjern and the probability density curve of ^{14}C-dates from sites containing Nøstvet axes in southeastern Norway in general, from c. 5600–5500 cal. BC (Fig. 8). In the following, the recurrent reductions in *Tilia*, which are regularly accompanied by increases in the probability density curve of ^{14}C-dates from sites containing Nøstvet axes, may confirm the selective use of lime wood for the production of implements. Conversely, the rises in *Betula*, succeeded by the increases in *Tilia*, along with declines in the probability density curves of ^{14}C-dates from sites containing Nøstvet axes, demonstrate woodland regeneration phases and, probably, periods of decreased utilisation of the wood forest resources.

Around 5500 cal. BC, the lake was located in the coastal hinterland, connected to the sea by a narrow, 600 m long stream. In the sheltered area around the lake, lime would have experienced favourable growing conditions. It might be assumed that humans exploited lime from the area around the lake. However, we cannot know whether wooden objects may have been worked at the lakeshore, or whether the raw material may have been brought to other places for processing. Surely, the possibility of transport of material or large implements by water must be considered, and here Lake Skogstjern would have provided excellent access to the sea and thus to other waterways along the coast. The recurrent opening up of the vegetation in the lake area may reflect this kind of short-term, repeated activity.

5. Conclusion

Palynological and archaeological data can support and supplement each other (cf. Hjelle et al., 2012). The information varies depending on the character and quality of the different data sets. While palynological data from lake coring represent quantitative information from a catchment area, archaeological finds can give insight into the qualitative use of specific locations. Archaeological data can also, as in this case, provide quantitative information on activity through temporal variation in site numbers. The variation in site numbers is here viewed in parallel with variations in the palynological data to infer landscape use. The archaeological data indicate temporal variation in the use of the coast, and the pollen data suggest that humans repeatedly used the forested landscape immediately behind the coast, as there are signs of both unintentional impact and deliberate human manipulation of the woodlands throughout the Mesolithic.

The accumulation of pollen indicating disturbed vegetation and the highest relative signal of micro-charcoal around the time of the isolation of the lake (8100–7640 cal. BC) correspond well with the archaeological evidence for human presence in the nearby area, which is documented through four excavated and almost 50 surveyed sites, shoreline dated to 8000–7600 cal. BC. A change in the use of the landscape is seen from this time onwards, reflecting the start of a generally more stable and sedentary settlement system.

The high amounts of microscopic charcoal particles at different stages between 6800 and 5000 cal. BC may reflect human activity. Together with small-scale openings around the lake throughout the late Middle Mesolithic and first part of the Late Mesolithic, there are signs of vegetation changes that occurred as a result of burning. This may reflect human manipulation of the landscape for improving the supply of useful plants, for attracting hunting prey or for extracting raw materials. The archaeological material shows comparatively few traces of activity in the early part of this time span and in the preceding centuries. This may be an example of how the palynological data can provide us with more information on the use of the landscape than can the archaeological data.

Between 5600 and 5000 cal. BC, there seems to have been a lot of human activity in Bamble. The excavated and surveyed sites illustrate that the coastal area was rather dense with sites. Possible human activity is documented in the pollen record in the form of traces of fire activities, reflected by elevated amounts of microscopic charcoal particles and pollen data reflecting the opening up of the forest canopy. The human impact in the palynological data during the last part of the Late Mesolithic is discussed in relation to the use of Lake Skogstjern as a resource extraction area for wood raw materials. The investigations in the catchment area of Lake Skogstjern demonstrate a rise in *Tilia* concurrent with the production of Nøstvet axes at the archaeological sites in Bamble. Repetitive gaps in the forest canopy are shown by the pollen data and by traces of fire activities. These can be linked with the presence and production of Nøstvet axes at the sites in the vicinity of Lake Skogstjern and can cautiously be interpreted as showing the use of *Tilia* as raw material for the production of wooden implements, watercraft and cordage.

Acknowledgements

The palynological and palaeo-ecological investigations, conducted at Kiel University, were financed by the cultural heritage management project E18 Rugtvedt-Dørdal, Museum of Cultural History, University of Oslo. Scientific exchange and field campaigns were supported by the Deutsch-Norwegisches Studienzentrum (DNZS) and further facilitated within the framework of the CRC 1266 Scales of Transformation at Kiel University. We would like to thank the project staff and field archaeologist for doing a great job in generating the archaeological data. Sincere thanks also go to the coring team of 2013, to Suzanne Needs for her help with the English language and to the two referees for their helpful comments and suggestions.

References

Alley, R.B., Mayewski, P.A., Sowers, T., Clark, P.U., 1997. Holocene climate instability: a prominent, widespread event 8200 yr ago. Geology 25, 483–486.

Antonsson, K., Seppä, H., 2007. Holocene temperatures in Bohuslän, southwestern Sweden: a quantitative reconstruction from fossil pollen data. Boreas 36, 400–410.

Behling, H., Street, M., 1999. Palaeoecological studies at the Mesolithic site at Bedburg-Königshov near Cologne, Germany. Vegetation History and Archaeobotany 8, 273–285.

Behre, K.-E., 1981. The interpretation of anthropogenic indicators in pollen diagrams. Pollen et Spores 23, 2252–2245.

Behre, K.-E., 2007. Evidence for Mesolithic agriculture in and around central Europe? Vegetation History and Archaeobotany 16, 203–219.

Bennett, K.D., Fossitt, J.A., Sharp, M.J., Switsur, V.R., 1990. Holocene vegetational and environmental history at Loch Lang, South Uist. New Phytologist 114, 281–298.

Berg-Hansen, I.M., 2009. Steinalderregistrering. Metodologi og forskningshistorie i Norge 1900–2000 med en feltstudie fra Lista i Vest-Agder. Kulturhistorisk Museum, Oslo.

Bergstrøm, B., 1999. Glacial geology, deglaciation chronology and sea-level changes in the southern Telemark and Vestfold counties, southeastern Norway. NGU Bulletin 435, 23–42.

Binford, L. 1980. Willow smoke and dogs' tails: hunter-gatherer settlement systems and archaeological site formation. American Antiquity 45, 4–20.

Bińka, K., Nitychoruk, J., 2013. Lightning-caused and human-induced forest fires as evidenced by *Pteridium* spores in selected Quaternary records from Poland. Studia Quaternaria 30(1), 29–40.

Bishop, R.R., Church, M.J., Rowley-Conwy, P.A., 2015. Firewood, food and human niche construction: the potential role of Mesolithic hunter-gatherers in actively structuring Scotland's woodlands. Quaternary Science Reviews 108, 51–75.

Bjerck, H.B., 2008. Norwegian Mesolithic trends: A review. In: Bailey, G., Spikins, P., (Eds.),Mesolithic Europe. Cambridge University Press, Cambridge, pp.60-106

Blackford, J.J., Edwards, K.J., Buckland, P.C., Dobney, K., 1996. Keith's Peat Bank, Hoy: Mesolithic human impact? In: Hall, A. (Ed.), The Quaternary of Orkney. Quaternary Research Association Field Guide (QRA), London, pp. 62–68.

Blackford, J.J., Innes, J.B., Hatton, J.J., Caseldine, C.J., 2006. Mid-Holocene environmental change at Black Ridge Brook, Dartmoor, SW England: a new appraisal based on fungal spore analysis. Review of Palaeobotany and Palynology 141, 189–201.

Bos, J.A.A., van Geel, B., Groenewoudt, B.J., Lauwerier, R.C.G.M., 2005. Early Holocene environmental change, the presence and disappearance of early Mesolithic habitation near Zutphen (The Netherlands). Vegetation History and Archaeobotany 15, 27–43.

Bos, J.A.A., Urz, R., 2003. Late Glacial and early Holocene environment in the middle Lahn river valley (Hessen, central-west Germany) and the local impact of early Mesolithic people – pollen and macrofossil evidence. Vegetation History and Archaeobotany 12, 19–36.

Boyd, W.E., Dickson, J.H., 1986. Patterns in the geographical distribution of the early Flandrian *Corylus* rise in southwest Scotland. New Phytologist 102(4), 615–623.

Breivik, H.M, Fossum, G., Solheim, S., 2017. Exploring human responses to climatic fluctuations and environmental diversity: two stories from Mesolithic Norway. Quaternary International. doi:10.1016/j.quaint.2016.12.019

Brown, T., 1997. Clearances and clearings: deforestation in Mesolithic/Neolithic Britain. Oxford Journal of Archaeology 16(2), 133–146.

Chandler, C., Cheney, P., Thomas, P., Traband, L., Williams, D., 1983. Fire as a natural process in forests. In: Chandler, C. (Ed.), Fire in forestry: forest fire behaviour and effects. Vol. 1. Wiley, New York, pp. 293–393.

Christensen, C., 1997. Både og sejlads I stenalderen. In: Petersen, L., Fischer, A., Aaby, B. (Eds.), 1997. Storebælt i 10.000 år. Mennesket, havet og skoven. A/S Storebæltsforbindelsen/Nationalmuseet, Copenhagen, pp. 282–289.

Damlien, H., 2013. Kulturhistorisk bakgrunn og faglige problemstillinger. In: Solheim, S., Damlien, H. (Eds.), E18 Bommestad-Sky. Undersøkelser av lokaliteter fra mellommesolitikum, Larvik kommune, Vestfold fylke. Portal Forlag, Kristiansand, pp. 23–30.

Damlien, H., 2016. Between tradition and adaption: long-term trajectories of lithic tool-making in South Norway during the postglacial colonization and its aftermath (c. 9500–7500 cal. BC). PhD-thesis UiS no. 297. University of Stavanger.

Damlien, H., Solheim, S., 2017 (in press). The pioneer settlement of eastern Norway. In: Blankholm, H.P. (Ed), The early economy and settlement in northern Europe: pioneering, resource use, coping with change. Equinox eBooks Publishing, United Kingdom. ISBN 9781781795170.

Danielsen, A., 1970. Pollen-analytical late Quaternary studies in the Ra district of Østfold, southeast Norway. Norwegian Universities Press, Bergen & Oslo.

Demuth, V., 2011. Rapport kulturhistorisk registrering Bamble kommune, Ny E18, sydlig trasé. Telemark fylkeskommune, Skien.

Dincauze, D.F. 2000. Environmental archaeology. Principles and practice. Cambridge Univrsity Press, Cambridge.

Düll, R., Kutzelnigg, H., 2005. Taschenlexikon der Pflanzen Deutschlands. Ein botanisch-ökologischer Exkursionsführer. Quelle & Meyer, Wiebelsheim.

Edlin, H.L., 1970. Trees, woods and man. New Naturalist Series, Collins, London.

Edwards, K.J., 1990. Fire and the Scottish Mesolithic: evidence from microscopic charcoal. In: Vermeersch, P.M., Van Peer, P. (Eds.), Contributions to the Mesolithic in Europe. Leuven University Press, Leuven, pp. 71–79.

Edwards, K. J., 2004. Palaeo-environments of the late Upper Palaeolithic and Mesolithic periods in Scotland and the North Sea: new work, new thoughts. In: Saville, A. (Ed.), Mesolithic Scotland and its neighbours: the early Holocene prehistory of Scotland, its British and Irish context and some northern European perspectives. Society of Antiquaries of Scotland, Edinburgh, Monograph series 28, pp. 55–72.

Edwards, K. J., Langdon, P. G., Sugden, H., 2007. Separating climatic and possible human impacts in the early Holocene: biotic response around the time of the 8200 cal. yr BP event. Journal of Quaternary Science 22, 77–84.

Edwards, K. J., 2009. The development and historiography of pollen studies in the Mesolithic of the Scottish islands. In: McCartan, S., Schulting, R., Warren, G., Woodman, P. C. (Eds.), Mesolithic Horizons: Seventh International Conference on the Mesolithic in Europe, Belfast 2005. Oxbow Books, Oxford, pp. 900–906.

Edwards, K. J., Schofield, J. E., Whittington, G., Melton, N. D., 2009. Palynology 'on the edge' and the archaeological vindication of a Mesolithic presence? The case of Shetland. In: Finlay, N., McCartan, S., Milner, N., Wickham-Jones, C. R. (Eds.), From Bann Flakes to Bushmills. Prehistoric Society Research Papers, no. 1, Oxbow Books, Oxford, pp. 113–123.

Eigeland, L., 2015. Maskinmennesket i steinalderen. Endring og kontinuitet i steinteknologi fram mot neolitiseringen av Øst-Norge. PhD-thesis. University of Oslo, Oslo.

Eigeland, L., Fossum, G., 2014. Vallermyrene 4. En lokalitet fra nøstvetfasen med spesialisert økseproduksjon. In: Reitan, G., Persson, P. (Eds.), Vestfoldbaneprosjektet. Arkeologiske undersøkelser i forbindelse med ny jernbane mellom Larvik og Porsgrunn. Bind 2. Seinmesolittiske, neolittiske og yngre lokaliteter i Vestfold og Telemark. Portal Forlag, Kristiansand, pp. 31–69.

Ellis, M.B., Ellis, J.P., 1988. Microfungi on miscellaneous substrates: an identification handbook. Croom Helm, London.

Feeser, I., Dörfler, W., Averdieck, F.-R., Wiethold, J., 2012. New insight into regional and local land-use and vegetation patterns in eastern Schleswig-Holstein during the Neolithic. In: Hinz, M., Müller, J. (Eds.), Siedlung, Grabenwerk, Großsteingrab. Studien zu Gesellschaft, Wirtschaft und Umwelt der Trichterbechergruppen im nördlichen Mitteleuropa, Bonn, pp. 159–190.

Glørstad, H., 2004. Metodiske resultater av Svinesundprosjektet: Registrering og utgravning. In: Glørstad, H. (Ed.), Svinesundprosjektet. Bind 4. Oppsummering av Svinesundprosjektet. Varia 57. Universitetets Kulturhistoriske museer, Universitetet i Oslo, Oslo, pp.85-98.

Glørstad, H., 2010. The structure and history of the Late Mesolithic societies in the Oslo Fjord area 6300–3800 BC. Bricoleur Press, Lindome.

Grøn, O., 2005. A Siberian perspective on the north European Hamburgian Culture: a study in applied hunter-gatherer ethnoarchaeology. Before Farming 2005(1). DOI: 10.3828/bfarm.2005.1.3.

Grøn, O., 2012. Our grandfather sent the elk – some problems for hunter-gatherer predictive modelling. Quartär 59, 175–188. doi: 10.7485/QU59_8.

Gumiński, W., Michniewicz, M., 2002. Forest and mobility: a case from the fishing campsite Dudka, Masuria, north-eastern Poland. In: Larsson, L. (Ed.), Mesolithic on the move. Oxbow books, Oxford, pp. 119–127.

Hawksworth, D.L., van Geel, B., Wiltshire, P.E.J., (2016). The enigma of the Diporotheca palynomorphs. Review of Palaeobotany and Palynology 235, 94–98.

Hafsten, U., 1957. Jordbrukskulturens Historie i Oslo – og Mjøstrakten Belyst ved Pollenanalytiske Undersøkelser. Viking 11/12, 51–74.

Havstein, J.A.H, 2017 (in press). Hegna øst 6. En mellommesolittisk fangstlokalitet. In: Solheim, S. (Ed.), E18 Rugtvedt–Dørdal. Arkeologiske undersøkelser av lokaliteter fra steinalder og jernalder i Bamble kommune, Telemark fylke. Portal Forlag, Kristiansand, pp. 451–471.

Hicks, S., 1993. Pollen evidence of localized impact on the vegetation of northernmost Finland by hunter-gatherers. Vegetation History and Archaeobotany 2, 137–144.

Hillbrand, M., Hadorn, P., Cugny, C., Hasenfratz, A., 2012. The palaeoecological value of *Diporotheca rhizophila* ascospores (Diporothecaceae, Ascomycota) found in Holocene sediments from Lake Nussbaumersee, Switzerland. Review of Palaeobotany and Palynology 186, 62–68.

Hjelle, K.L. Solem, T., Halvorsen, L.S., Åstveit, 2012. Human impact and landscape utilisation from the Mesolithic to medieval time traced by high spatial resolution pollen analysis and numerical methods. Journal of Archaeological Science 39, 1368–1379.

Holst, D., 2010. Hazelnut economy of early Holocene hunter-gatherers: a case study from Mesolithic Duvensee, northern Germany. Journal of Archaeological Science 37, 2871–2880.

Hörnberg, G., Bohlin, E., Hellberg, E., Bergman, I., Zackrisson, O., 2005. Effects of Mesolithic hunter-gatherers on local vegetation in a non-uniform glacioisostatic land uplift area, northern Sweden. Vegetation History and Archaeobotany 15, 13–26.

Huntley, B., 1993. Rapid early-Holocene migration and high abundance of hazel (*Corylus avellana* L.): alternative hypotheses. In: Chambers, F.M. (Ed.), Climate change and human impact on the landscape. Studies in Palaeoecology and Environmental Archaeology. Chapman and Hall, London, pp. 205–215.

Høeg, H.I., 1980. En pollenanalytisk undersøkelse i Storgamafeltet i Nissedal. SNSF-Rapport 57/80. Prosjektet "Sur nedbørs virkning på skog og fisk", Oslo & Ås.

Høeg, H.I., 1982. Vegetational development from about 12 000 to 6 000 years B.P. in the counties of Agder and Telemark, South Norway. Norsk Geografisk Tidsskrift 36, 211–224.

Innes, J.B., Simmons, I.G., 1988. Disturbance and diversity: floristic changes associated with pre-elm decline woodland recession in north east Yorkshire. In: Jones, M. (Ed.), Archaeology and the flora of the British islands. University Committee for Archaeology, Oxford, pp. 7–20.

Innes, J.B., Simmons, I.G., 2000. Mid-Holocene charcoal stratigraphy, fire history and palaeoecology at North Gill, North York Moors, UK. Palaeogeography, Palaeoclimatology, Palaeoecology 164, 151–165.

Innes, J.B., Blackford, J., 2003. The ecology of late Mesolithic woodland disturbances: model testing with fungal spore assemblage data. Journal of Archaeological Science 30, 185–194.

Innes, J.B., Blackford, J.J., Chambers, F.M., 2006. *Kretzschmaria deusta* and the northwest European mid-Holocene *Ulmus* decline at Moel y Gerddi, North Wales, United Kingdom. Palynology 30, 121–132.

Innes, J., Blackford, J., Simmons, I., 2010. Woodland disturbance and possible land-use regimes during the Late Mesolithic in the English uplands: pollen, charcoal and non-pollen palynomorph evidence from Bluewath Beck, North York Moors, UK. Vegetation History and Archaeobotany 19, 439–452.

Innes, J., Blackford, J., Rowley-Conwy, P., 2013. Late Mesolithic and early Neolithic forest disturbance: a high resolution palaeoecological test of human impact hypotheses. Quaternary Science Reviews 77, 80–100. doi:10.1016/j.quascirev.2013.07.012

Iversen, J., 1973. The development of Denmark's nature since the last glacial. Danmarks Geologiske Undersøgelse. V. række 7C, 1–126.

Jaksland, L., 2005. Hvorfor så mange økser? En tolkning av funnene fra den klassiske Nøstvetboplassen I Ås, Akershus. Hovedfagsoppgave i nordisk arkeologi. IAKH, Det humanistiske fakultet, Universitetet i Oslo, Oslo.

Klooß, S., 2015. Mit Einbaum und Paddel zum Fischfang. Holzartefakte von endmesolithischen und frühneolithischen Küstensieldungen an der südwestlichen Ostseeküste. Wachholtz, Neumünster.

Kolstrup, E., 1990. Early and middle Holocene vegetational development in Kurarp (Scania, South Sweden). Review of Palaeobotany and Palynology 63, 233–257.

Koxvold, L.U., 2013b. Hovland 2. En mellommesolittisk lokalitet med flere opphold og et råstoffdepot. In: Solheim, S., H. Damlien (Eds.), E18 Bommestad-Sky. Undersøkelser av lokaliteter fra mellommesolitikum, Larvik kommune, Vestfold fylke. Portal Forlag, Kristiansand, pp. 78–105.

Kramer, A., Bittmann, F., Nösler, D., 2014. New insights into vegetation dynamics and settlement history in Hümmling, north-western Germany, with particular reference to the Neolithic. Vegetation History and Archaeobotany 23, 461–478.

Kuneš, P., Pokorný, P., Šída, P., 2008. Detection of the impact of early Holocene hunter-gatherers on vegetation in the Czech Republic, using multivariate analysis of pollen data. Vegetation History and Archaeobotany 17, 269–287.

Låg, J., Norges Landbrukshøgskole, 1983. Soil Map Norway – Jordbunnskart. Scale: 2,000,000.

Latalowa, M., 1992. Forest changes at the Mesolithic/Early Neolithic transition and in the Migration Period on Wolin Island (NW Poland). In: Frenzel, B. (Ed.), Evaluation of land surfaces cleared from forests by prehistoric man in early Neolithic times and the time of migrating Germanic tribes. European Science Foundation, Strasbourg, pp. 139–155.

Lundquist, N., 1972. Nordic Sordariaceae s. lat. Symbolae Botanicae Upsalienses 20(1), 1–374.

Mansrud, A., 2014. Mobil eller bofast? Erverv, landskap og mobilitet i mellommesolittiske kystsamfunn i Øst-Norge (8300–6300 f.Kr.). Norsk Maritimt Museums Årbok 2013, 67–108.

Mason, S.L.R., 2000. Fire and Mesolithic subsistence – managing oaks for acorns in northwest Europe? Palaeogeography, Palaeoclimatology, Palaeoecology 164, 139–150.

Mellars, P., Dark, P., 1998. Star Carr in Context: new archaeological and palaeoecolgical investigations at the early Mesolithic site of Star Carr, North Yorkshire McDonald Institute for Archaeological Research, Cambridge.

Mellars, P., 1976. Fire ecology, animal populations and man: a study of some ecological relationships in prehistory. Proceedings of the Prehistoric Society 42, 15–45.

Meyer, A.D., 2008. Rapport kulturhistorisk registrering Bamble kommune, Stokke gård. Telemark fylkeskommune, Skien.

Mighall, T.M., Timpany, S., Blackford, J.J., Innes, J.B., O’Brien, C.E., O’Brien, W., Harrison, S., 2008. Vegetation change during the Mesolithic and Neolithic on the Mizen Peninsula, Co. Cork, south-west Ireland. Vegetation History and Archaeobotany 17, 617–628.

Mikkelsen, E., 1989. Fra jeger til bonde: Utviklingen av jordbrukssamfunn i Telemark i steinalder og bronsealder. Universitetets oldsaksamlings skrifter. Ny rekke 11. Universitetets Oldsaksamling, Oslo.

Moore, J., 1996. Damp squib: how to fire a major deciduous forest in an inclement climate. In: Pollard, T., Morrison, A. (Eds.), The early prehistory of Scotland. Edinburgh University Press, Edinburgh, pp. 62–73.

Moore, J., 2000. Forest fire and human interaction in the early Holocene woodlands of Britain. Palaeogeography, Palaeoclimatology, Palaeoecology 164, 125–137.

Nedkvitne, K., Gjerdåker, J., 1997. Lind i norsk natur og tradisjon. Norsk skogbruksmuseum Særpublikasjon 12. Norsk Skogbruksmuseum, Elverum.

Odgaard, U., 1993. Arkeologisk rapport, E18 Rugtvedt, Bamble kommune, Telemark fylke. Topographical archive. Museum of Cultural History, University of Oslo, Oslo.

Olsen, M., 2012. Rapport arkeologisk registrering E18 Rugtvedt-Dørdal. Telemark Fylkeskommune, Skien.

Persson, P., 2014a. Prestemoen 1. En plats med ben från mellanmesolitikum. In: Melvold, S., P. Persson (Eds.), Vestfoldbaneprosjektet. Arkeologiske undersøkelser i forbindelse med ny jernbane mellom Larvik og Porsgrunn. Bind 1. Tidlig- og mellommesolittiske lokaliteter i Vestfold og Telemark. Portal Forlag, Kristiansand, pp. 202–227.

Persson, P., 2014b. Naturvetenskap. In: Melvold, S., P. Persson (Eds.), Vestfoldbaneprosjektet. Arkeologiske undersøkelser i forbindelse med ny jernbane mellom Larvik og Porsgrunn. Bind 1. Tidlig- og mellommesolittiske lokaliteter i Vestfold og Telemark. Portal Forlag, Kristiansand, pp. 76–87.

Poska, A., Saarse, L., Veski, S., 2004. Reflections of pre- and early-agrarian human impact in the pollen diagrams of Estonia. Palaeogeography, Palaeoclimatology, Palaeoecology 29, 37–50.

Prøsch-Danielsen, L., 1996. Vegetation history and human impact during the last 11500 years at Lista, the southernmost part of Norway: based primarily on Professor Ulf Hafsten's material and diary from 1955–1957. Norsk Geografisk Tidsskrift 51, 83–101.

Puschman, O., 2005. Nasjonalt referansesystem for landskap – Beskrivelse av Norges 45 landskapsregioner. NIJOS rapport 10/05.

Rackham, O., 1986. The history of the countryside. Dent, London.

Regnell, M., 2012. Plant subsistence and environment at the Mesolithic site Tågerup, southern Sweden: new insights on the "Nut Age". Vegetation History and Archaeobotany 21, 1–16.

Reitan, G., 2016. Mesolittisk kronologi i Sørøst-Norge – et forslag til justering. Viking 79, 23–52.

Rodwell, J.S., 1991. British plant communities. Vol 2. Mires and heaths. Cambridge University Press, Cambridge.

Rowley-Conwy, P., Layton, R. 2011. Foraging and farming as niche construction: stable and unstable adaptations. Philosophical Transactions of the Royal Society B 366, 849–862.

Rowley-Conwy, P. 2017. To the Upper Lake: Star Carr revisited – by birchbark canoe. In: Rowley-Conwy, P., Sergeantson, D., Halstead, P. (Eds.), Economic zooarchaeology: studies in hunting, herding and early agriculture. Oxbow Books, Oxford; Philadelphia. JSTOR, www.jstor.org/stable/j.ctt1s4751q.28.

Ryan, P.A., Blackford, J.J., 2010. Late Mesolithic environmental change at Black Heath, south Pennines, UK: a test of Mesolithic woodland management models using pollen, charcoal and non-pollen palynomorph data. Vegetation History and Archaeobotany 19, 545–558.

Schülke, A., 2017. Prosjektplan og faglige problemstillinger for E18 Rugtvedt-Dørdal. Mennesker og kystsonen i steinalderen – variajon og kontinuitet. In: Solheim, S. (Ed.), E18 Rugtvedt-Dørdal. Arkeologiske undersøkelser av lokaliteter fra steinalder og jernalder i Bamble kommune, Telemark fylke. Portal Forlag, Kristiansand, pp. 17–18.

Seppä, H., Hammarlund, D., Antonsson, K., 2005. Low-frequency and high-frequency changes in temperature and effective humidity during the Holocene in south-central Sweden: implications for atmospheric and oceanic forcings of climate. Climate Dynamics 25, 285–297.

Simmons, I.G., Innes, J.B., 1996. Disturbance phases in the mid-Holocene vegetation at North Gill, North York Moors: form and process. Journal of Archaeological Science 23, 183–191.

Solheim, S., 2013. E18-lokalitetenes relasjonelle struktur. In: Solheim, S., H. Damlien (Eds.), E18 Bommestad-Sky. Undersøkelser av lokaliteter fra mellommesolitikum, Larvik kommune, Vestfold fylke. Portal Forlag, Kristiansand, pp. 276–283.

Solheim, S., Olsen, D.E.F., 2013. Hovland 3. Mellommesolittisk boplass med hyttetuft. In: Solheim, S., H. Damlien (Eds.), E18 Bommestad-Sky. Undersøkelser av lokaliteter fra mellommesolitikum, Larvik kommune, Vestfold fylke. Portal Forlag, Kristiansand, pp. 198–235.

Solheim, S., H. Damlien (Eds.), 2013. E18 Bommestad-Sky. Undersøkelser av lokaliteter fra mellommesolitikum, Larvik kommune, Vestfold fylke. Portal Forlag, Kristiansand.

Solheim, S., (Ed.) 2017. E18 Rugtvedt-Dørdal. Arkeologiske undersøkelser av lokaliteter fra steinalder og jernalder i Bamble kommune, Telemark fylke. Portal Forlag, Kristiansand.

Sørensen, R., 1996. Oslofjord area. In: Berglund, B. (Ed.), Palaeoecological events during the last 15,000 years: regional syntheses of palaeoecological studies of lakes and mires in Europe. Wiley, New York.

Sørensen, R., Henningsmoen, K.E.,. Høeg, H.I., Gälman, V., 2014. Holocene landhevningsstudier i søndre Vestfold og sørsøstre Telemark – revidert kurve. In: Melvold, S., P. Persson (Eds.), Vestfoldbaneprosjektet. Arkeologiske undersøkelser i forbindelse med ny jernbane mellom Larvik og Porsgrunn kommune. Bind 1. Tidlig- og mellommesolittiske lokaliteter i Vestfold og Telemark. Portal Forlag, Kristiansand, pp. 236–247.

Sørensen, R., Høeg, H.I. , Gälman, V., 2016. Revidert strandlinjeforskyvningskurve for Bamble. Report for E18 Rugtvedt-Dørdal. Museum of Cultural History, University of Oslo, Oslo.

Tinner, W., Conedera, M., Gobet, E., Hubschmid, P., Wehrli, M., Ammann, B., 2000. A palaeoecological attempt to classify fire sensitivity of trees in the southern Alps. The Holocene 10(5), 565–574.

Van Geel, B., 1978. A palaeoecological study of Holocene peat bog sections in Germany and the Netherlands. Review of Palaeobotany and Palynology 25, 1–120.

Van Geel, B., Buurman, J., Brinkkemper, O., Schelvis, J., Aptroot, A., van Reenen, G., Hakbijl, T., 2003. Environmental reconstruction of a Roman period settlement site in Uitgeest (The Netherlands), with special reference to coprophilous fungi. Journal of Archaeological Science 30, 873–883.

Van Geel, B., Aptroot, A., 2006. Fossil ascomycetes in Quaternary deposits. Nova Hedwigia 82, 313–329.

Wacnik, A., 2005. Wpływ działalności człowieka mezolitu i neolitu na szatę roślinną w rejonie Jeziora Miłkowskiego (Kraina Wielkich Jezior Mazurskich). In: Wasylikowa, K., Lityńska-Zając, M., Bieniek Kraków, A. (Eds.), Roślinne ślady człowieka. W. Szafer Institute of Botany, Polish Academy of Sciences, Kraków, pp. 9–27.

Warren, G., Davis, S., McClatchie, M., Sands, R., 2014. The potential role of humans in structuring the wooded landscapes of Mesolithic Ireland: a review of data and discussion of approaches. Vegetation History and Archaeobotany 23, 629–646.

Welinder, S., 1981. The disappearance of hunting-gathering economy. In: Gramsch, B. (Ed.), Mesolithikum in Europa. Veröffentlichungen des Museums für Ur- und Frühgeschichte Potsdam 14/15, Berlin, pp. 151-163.

Whitehouse, N.J., Kirleis, W., 2014. The world reshaped: practices and impacts of early agrarian societies. Journal of Archaeological Science 51, 1–11.

Whitehouse, N.J., Schulting, R.J., McClatchie, M., Barratt, P., McLaughlin, T.R., Bogaard, A., Colledge, S., Marchant, R., Gaffrey, J., Bunting, M.J., 2014. Neolithic agriculture on the European western frontier: the boom and bust of early farming in Ireland. Journal of Archaeological Science 51, 181–205.

Wieckowska, M., Dörfler, W., Kirleis, W., 2012. Holocene history of environment and human impact on two islands in the Ostholstein lakeland area, northern Germany. Vegetation History and Archaeobotany 21, 303–320.

Wieckowska-Lüth, M., Kirleis, W., Dörfler, W., 2017. Holocene history of landscape development in the catchment of Lake Skogstjern, southeastern Norway, based on a high-resolution multi-proxy record. The Holocene, online first.

Wilkinson, J., Vedmore, A., 2001. Craft willows in Scotland. Millennium Forest for Scotland and Forestry Commission.

www.data.kartverket.no

www.lueth-archaeologie.de

Zvelebil, M., 1994. Plant use in the Mesolithic and its role in the transition to farming. Proceedings of the Prehistoric Society 60, 35–74.

Østmo, E., 1995. Nøstvedtboplassen på Dælenengen i Oslo. Universitetets Oldsaksamlings første boplassundersøkelse. Universitetets Oldsaksamling årbok 1993–1994, 91–120.