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Demographic developments in Stone Age coastal western Norway by proxy of radiocarbon dates, stray finds and palynological data

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ABSTRACT

This paper presents a multi-proxy approach to coastal Stone Age demography. It uses the district Hordaland, western Norway as a case and applies the proxies SPD (summed probability distributions) of radiocarbon dates and stray find distributions. These are compared to pollen-based landscape reconstructions. Large numbers of Stone Age sites have been surveyed and excavated in western Norway during the last few decades, mainly because of modern development and cultural heritage management. This work has produced significant amounts of radiocarbon dates. The data has, until now, not been sufficiently organized and systematized for the purpose of doing research on long-term changes. The same is true for the many stray finds, which are stored at University Museum of Bergen. During the last decades, methodological development in palynology has made compilation of data and new vegetation reconstructions possible. For the first time, these dispersed datasets from the district Hordaland are brought together for comparative purposes, with a specific goal to study relative demographic changes. The hypothesis is that during the Stone Age, demographic change accompanied big cultural transformations in the transition from LM (late Mesolithic) to EN (early Neolithic) c. 5950 cal BP and between MN (middle Neolithic) and LN (late Neolithic) c. 4300 cal BP. This study partly supports the hypothesis, as the changes in the SPD and the stray finds during the transition to the late Neolithic clearly reflect marked population growth, related to the introduction of agriculture, at the same time as the pollen data reveal forest clearance. The LM-EN transition is less clearly connected to demographic change. Generally, up until the transition to the LN, the data indicate that there was gradual demographic growth with marked fluctuations within a forested landscape. Although the proxies sometimes co-vary for the different periods, they may also display conflicting patterns, and this strengthens the argument that a multi-proxy approach to demographic studies is to be recommended.

1. Introduction

Population dynamics have triggered some of the most significant transformations in human history, and during the last few years investigations of demography and its relationship to cultural and environmental change has become a thriving field in Stone Age archaeology. This is due to better methods for documentation, increasing availability of “big data”, and advanced statistical tools for processing it. In this context, SPD (summed probability distribution) of radiocarbon dates is commonly used (e.g. Hinz et al., 2012; Riede, 2009; Shennan and Edinborough, 2007; Shennan et al., 2013), and recently other proxies have also been applied to this purpose in combination with SPD (Apel et al., 2018; Crombé and Robinson, 2014; French, 2015; Lawrence et al., 2021; Palmisano et al., 2017; Roberts et al., 2019; Tallavaara and Pesonen, 2020). In this article, SPD will be applied and we will also apply the quantitative and spatial/chronological distribution of stray finds. The results from these will be compared to pollen-based land-cover changes, to see if there is a relationship between population size and openness of the landscape (e.g. Gaillard et al., 2010; Kuosmanen et al., 2018; Lechterbeck et al., 2014; Palmisano et al.,

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2017).

The coasts of northern Europe were arenas for major cultural developments during the early Holocene (e.g. Bjerck, 2008; Blankholm, 2008; Damm et al., 2020; Fisher, 2002; Glørstad, 2010; Zvelebil, 2006). Productive environments and a broad spectrum of available resources could potentially support large hunter-fisher-gatherer (HFG) populations and be suitable for early farmers. We will therefore approach interdisciplinary data from coastal western Norway as a case to study the demographic backdrop to known cultural changes as well as human-environmental processes. According to Zahid et al. (2016), HFG populations worldwide grew exponentially after the beginning of the Holocene, c. 11.700 cal BP, and this seem to be confirmed by SPD analyses from northern and eastern Norway (Jørgensen, 2020; (Solheim, 2020). We ask if this was also the case in Stone Age in western Norway from the first colonization c. 11.500 cal BP and onwards. We hypothesize that two specific cultural transformations during this period were associated with marked demographic changes. These are:

- Abrupt changes in the material culture repertoire in the EN c. 5950 cal BP, when HFG groups became fully sedentary, and the resource-base and landscape openings were extended (e.g. Bergsvik, 2001; Hjelle et al., 2018; Olsen, 1992).
- The breakthrough of agriculture in the LN c. 4300 cal BP, when the main settlement areas were relocated from the outer coast to the interior and fjords (e.g. Hjelle et al., 2006; Olsen, 2013).

To approach this problem, we will use data from the district Hordaland (Fig. 1). In this area a high number of excavations and surveys, including palynological work, have been performed and published mainly as part of cultural heritage management. Archaeological and palynological research has also been extensive, a detailed archaeological chronological resolution is established and missing temporal and spatial data have been identified. The area can be regarded as culturally homogenous, which makes comparisons less problematic and easier to control for taphonomic losses, compared to larger regions (Timpson et al., 2014:550; Williams, 2012:581). In our case, we have a rather robust dataset when it comes to the sheer quantity. This combination of cultural/spatial homogeneity and good quality archaeological and environmental data makes Hordaland ideal as a study area for long-term relative demographic fluctuations in a temperate coastal zone. By using interdisciplinary proxies in the present study, we aim to identify similarities/differences in the datasets to test our hypothesis. We will also consider possible discrepancies between them, a task that potentially has methodological implications.

Fig. 1. Middle and Southern Scandinavia with the study area (Hordaland) marked.

2. Regional setting

Western Norway can be subdivided into several physiographical zones (Puschmann, 2005). In Hordaland, covering an area of 15.460 m^2, the outer coast is characterized by a rim of low-lying islands exposed to the North Sea. These islands effectively protect navigation by boat on the inside, and here, numerous shallow straits and channels provide rich fisheries and marine mammal hunting due to strong tidal currents. Further east, the outer fjord basins consist of short fjords and the mouths of long ones. In this zone, there are mountains of considerable heights, and the fjords are also deeper than the straits at the coast. In the middle and inner fjord zones water depths may be more than 860 mbsl (Hardanger fjord) and the mountains have heights up to more than 1500 masl. Side valleys drain into the main fjords. Fisheries are also practiced in the fjord systems, but they yield considerably less than at the outer coast. The climate in the Stone Age was warmer than today (Eldevik et al., 2014) and most of the area became forested with deciduous or mixed forests (e.g. Hjelle et al., 2018; Kaland, 1984; Mehl and Hjelle, 2015; Paus and Moe, 1996), in which elk, red deer, wild boar and fur-bearing animals were hunted (e.g. Hufthammer, 1992, 2015). During the relevant period, sea-level changes were considerable and varied. In Hordaland, the marine limit was 30–40 masl at the outer coast, and c. 110 masl in the inner part of the Hardanger fjord, due to the rate of rebound increasing from west to east (Mangerud et al., 2013). C. 9000–7500 cal BP the Tapes transgression flooded areas as much as 6–7 m at the outer coast, causing destruction of shore bound Early and Middle Mesolithic sites (Bjerck, 2008). A tsunami at c. 8100 cal BP may also have caused destructions (Bondevik et al., 1998). Stone Age populations occupied coastal as well as fjord areas, whereas the eastern mountain plateau was less in use from the west (but was frequently used by eastern populations). C14-dates and stray finds from the mountains (above c. 500 masl) are therefore omitted from the analysis.

Earlier work on Stone Age western Norway has discussed issues of demography only to a minimal degree. However, based on quantification of the consumption of quarried greenstone adzes, Olsen and Alsaker (1984) calculated that the "southern territory" (covering 31.000 km^2 mainly Hordaland and the county Rogaland to the south) had a population of a minimum of 114 and a maximum of 558 individuals, resulting in a population density between 1/270 and 1/55 per km (Olsen and Alsaker, 1984:99). These numbers represent the entire quarry period (c. 8000–4350 cal BP), and do not consider possible chronological fluctuations. A study based on site counts has focused on changes during the Mesolithic-Neolithic transition, with the local "hot-spot" area Fosnstraumen as a case. It showed that site numbers as well as site sizes were much higher during the early/middle Neolithic than the late Mesolithic, suggesting demographic growth in combination with the effects of increased sedentism (Bergsvik, 2001:21). A question, however, is how valid this result is on a regional scale. More recently, Nielsen et al. (2019) have performed an SPD of radiocarbon dates from southern Norway. Their study considers only the Neolithic, and radiocarbon dates from western Norway have been presented together with dates from eastern/central Norway, which mask possible regional differences. Even so, their result uncovers important general changes, such as a marked increase during the EN, fluctuations during the succeeding period and a decrease during the MNB. Based on the application of the so-called Cologne Protocol, Lundström et al. (2021) have also suggested that the pioneer (EM) populations in Norway had low population size and densities.

Generally, palynological investigations in the study area have not aimed to relate vegetation development to demographic patterns in the Stone Age. However, the understanding of human impact on the vegetation has been in focus for nearly a century (e.g. Bakka and Kaland, 1971; Bjerck, 1988; Fægri, 1944; Halvorsen and Hjelle, 2017; Hjelle, 1992; Kaland, 1986, 1992; Mehl et al., 2015; Mehl and Hjelle, 2016; Midtbø, 2001; Overland and Hjelle, 2009). Interpretation of human impact has, traditionally, been based on the presence of microscopic charcoal and anthropogenic indicators (cf. Behre, 1981), with a strong attention towards the introduction and development of farming. Forest disturbances by the HFG populations have been less in focus, although the importance of hazelnuts in the Mesolithic is well documented in macro remains from archaeological excavations in the region, as well as the need for firewood and building material. Some diagrams from the vicinity of Mesolithic sites have decreased tree pollen percentages at the time of occupation (e.g. Kaland, 1992; Midtbø, 2001), but generally high pollen production of trees compared to open-land communities is a problem in relation to interpreting vegetation openness based on pollen data, especially in forest dominated periods. Recently, pollen-based landscape reconstruction models have shown the effect of people on the landscape, and indirectly demographic pattern, throughout the Stone Age in the region (Hjelle et al., 2018; Mehl and Hjelle, 2015). A case study from Vingen, an area of Mesolithic rock art production to the north of our study area, is methodologically important as it confirms the relationship between several radiocarbon dates and a local decrease in estimated tree cover. This is assumed to reflect the effect of more people present in Vingen at the end of the Mesolithic compared to the centuries before and after (Hjelle and Lødøen, 2017).

3. Material and methods

3.1. SPD analysis

The use of SPD in archaeology, its limitations and considerations has been described and critically discussed by several authors (Attenbrow and Hiscock, 2015, 2016; Crema and Bevan 2020; Crema et al., 2016, 2017; Timpson et al., 2014; Timpson et al., 2015; Torfing, 2015; Smith, 2016; Williams, 2012; Williams and Ulm, 2016). Although we are aware of the need for caution in using radiometric dates as a proxy for prehistoric population change, we accept the underlying premise, that there is a general positive correlation between prehistoric human activity and the abundance of archaeological C14-dates (Crema et al., 2016; Williams, 2012). In our analysis we use the rolling mean of 200 years as proposed by Timpson et al. (2014) to counter the effect of wiggles in the calibration curve (Williams, 2012) and for the same purpose also employ unnormalized dates (Crema and Bevan 2020: 5–6). We employ the hypothesis testing of Crema et al. (2016) of our empirical data against statistical confidence envelopes of two null models: a uniform model assuming no change in population with time and an exponential model of population growth. The number of simulations in the hypothesis testing using the Monte Carlo permutation test is 1000. The C14-dates are calibrated using the IntCal20 calibration curve (Reimer et al., 2020) using the rcarbon package in R (Bevan and Crema, 2020), which was also employed for the SPD-analysis.

The data is gathered from radiocarbon dated coastal sites where "coastal" in this context also includes sites that are situated close to fjords (Fig. 2).[1] In general, the context of the dates is either settlement sites, or – increasingly for the later phases of the period – fossilized agricultural horizons. The dataset contains a total of 703 dates, spanning between 10.810 cal BP as the hitherto oldest date from the region to 3000 cal BP, which is a chosen ending point situated well into the Bronze Age to avoid edge effects on the distributions. A narrower study on the period 8000 cal BP to 3750 cal BP encompasses 518 dates. The data includes samples processed both through conventional decay counting methods and Accelerator Mass Spectrometry (AMS), and most of the dated material is charcoal or hazelnut shells, making the marine reservoir effect negligible (cf. Stuiver and Brazuinas, 1993). The ΔT (Williams, 2012: 580–582) for the entire database is 62 and for the subsample 65. The dates derive from a total of 238 different sites, with three heavily investigated, multi-period sites accounting for almost 20% (Fig. 3). To reduce bias from over-sampling of certain sites within the dataset, binning by aggregating samples from the same site (e.g. Crema and Bevan, 2020; Shennan et al., 2013) has been used. For example, the excavations at the multiperiod site of Kotedalen (Olsen, 1992), which account for almost 10% of our dates, had an explicit interest in the introduction of domesticates in the region. Such site-specific research biases can be countered by binning together individual dates. We choose the 200-year bin after evaluating 50, 100 and 200-year bins, seeing that all these display a similar trend. 200-year bins also follow what has been the norm in previous SPD-studies on long-term change in Norway and Fennoscandia (Jørgensen, 2020; Jørgensen and Riede, 2019; Solheim and Persson, 2018; Tallavaara and Pesonen, 2020).

3.2. Stray finds

Stray finds are artifacts found by lay people (non-archaeologists) and delivered to the University museums. The first stray finds were acquired already during the early 1800s. Since the national law of antiquities in Norway was approved in 1905 such finds have been the property of the state and must be handed in to the authorities when found. As a result, the Stone Age collections at the University Museum of Bergen currently consists of c. 1650 stray finds from Hordaland.

The quantitative and spatial distribution of stray finds may be used as a population proxy if the relevant types are succeeding each other chronologically with little overlap, and under the premise that the compared artifacts from the different periods "represent" people in similar ways, stated simply that few stray finds mean few people and many finds mean many people. Obviously, this premise is problematic and difficult to control, and there are three main challenges: (1) differences in the shapes might make some artifact-types more easily recognized than others by lay people, (2) there were different depositional practices for the different artifact types in different periods, making some easier to find than others, and (3) extraction and consumption patterns might have varied over time.

Concerning (1) the stray finds in the database mainly consist of large artifacts such as axes/adzes, hatchets, daggers, and spears, however, there are also smaller finds, like projectile points, scrapers, blades, and even flakes. To have a comparable set of data, only large artifacts (1045 finds) are included (Table 1).

These are all considered easily (and similarly) recognizable for a lay person, and thus comparable across the types. Small artifacts are left out of the analysis, because they are considered less recognizable and if spotted, perhaps less important for people to

[1] The sites used here are only the ones that have yielded radiocarbon dates. Many more Stone Age sites are surveyed and excavated in this district, and they are currently being processed for more detailed demographic studies.

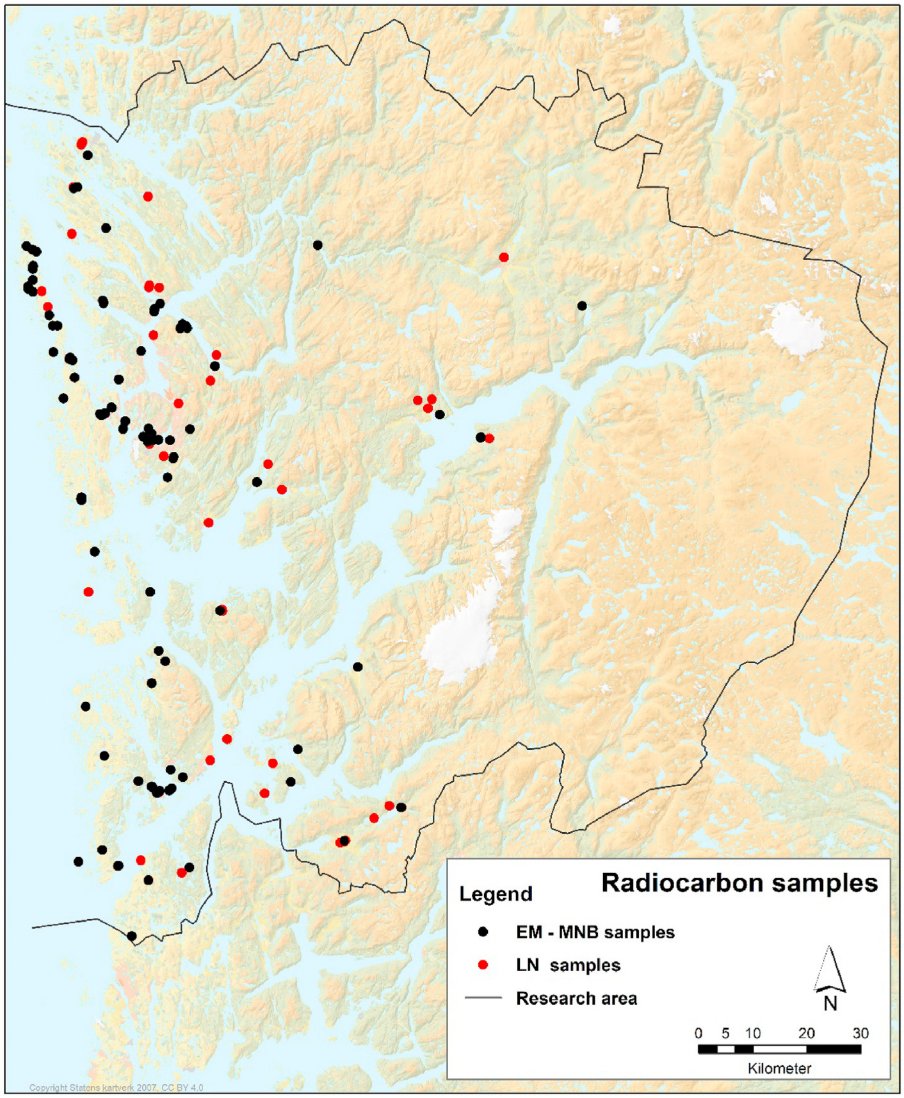

Fig. 2. Distribution of radiocarbon dated sites in Hordaland spanning the early Mesolithic to the late Neolithic. EM-MNB (470 dates from hunter-fisher-gatherer settlements), LN (78 dates from agricultural settlements). Bronze Age sites are not included.

hand in to the authorities, possibly causing uneven distribution patterns. Furthermore, local lay people who do in fact recognize small artifacts would probably have a special insight into archaeology, and including artifacts delivered by such individuals might lead to a bias on certain periods or districts.

Concerning (2) large artifacts may stem from different archaeological contexts and based on general knowledge on depositions during the Stone Age of Norway, there are three main alternatives: residential sites, graves, and placed deposits. In addition, some artifacts could be lost items. One might hypothesize that artifacts from plowed up residential sites would be easier to spot than others, because they would lie in shallower soils, and this would create a bias in the dataset if mainly related to certain periods. A problem, however, is that the context information connected to the individual artifacts are most often sparse, and at best equivocal, making it difficult to securely adjust for such differences, even if they might have been important.

Another, and perhaps more serious issue is that the stray finds stem from HFG populations ranging from the MM to the MNA, and farming populations in the LN. Present farmers cultivate the same areas as the LN farmers, and these areas only minimally overlap with the settlement areas of the older HFG populations. Since most of the stray-finds have been delivered to the museum by modern farmers, it is thus likely that finds from the LN is over-represented in the database compared to the older finds. This need to be taken into consideration when discussing the results.

Concerning (3) some of the artifacts used in this analysis were quarried and produced in western Norway, while others were imported to this region. Some artifacts were also mainly working tools (axes/adzes), whilst others may mainly have had symbolic significance (hatchets/daggers). These differences probably implied variations in accessibility as well as use and deposition for the individual types, and they may therefore “represent” population in different ways. Nevertheless, even if this factor must be considered, we find it difficult to adjust for their values as population proxies, since we lack concrete calculations of these relationships.

To be used as a population proxy, the stray finds have been reclassified, dated according to the established typological/chronological framework, and they are georeferenced (Bergsvik and Aksdal, 2019). We apply artifacts for which the chronological distributions are only within the compared periods. It should be noted that some of the applied Neolithic finds were also minimally used

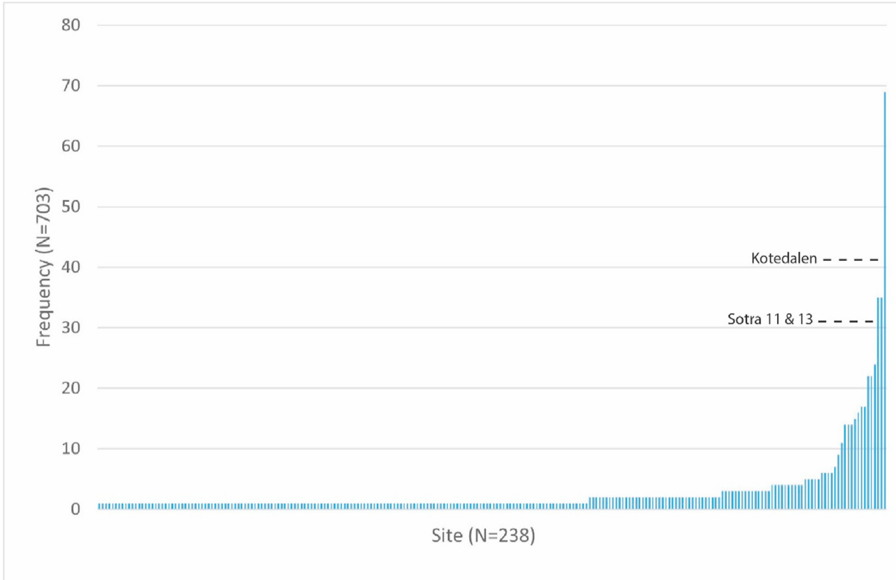

Fig. 3. Number of C14-dates per individual site. Note that the multi-phased sites of Kotedalen (Olsen 1992), and Sotra localities 11 and 13 (Åstveit et al., in prep) together constitute almost 20% of all dates.

Table 1
Stray finds from Hordaland and chronological frame.

Stray finds	Total	Chronology cal BP	Period	Reference to chronological work
Chubby stone adzes	392	9950–5950	MM/LM	(Bjerck, 1986; Gjerland, 1984; Olsen, 1981)
Flat-oval stone adzes	31	9950–5950	MM/LM	(Bjerck, 1986; Gjerland, 1984; Olsen, 1981)
Stone hatches (star/cross-shaped, and ordinary)	52	9450–7650	MM/LM	(Glørstad, 2002; Olsen, 1992; Skår, 2003)
Vespestad adzes	144	5950–5250	EN	(Nærøy, 1988, 1993; Olsen, 1992)
Vestland adzes	93	5250–4650	MNA	(Nærøy, 1988, 1993; Olsen, 1992)
MNB axes/adzes[a]	96	4650–4300	MNB	(Malmer, 1962)
Flint daggers (type I–V)	96	4300–3750	LN	(Lomborg, 1973; Vandkilde, 1996)
Simple shafthole adzes	81	4300–3750	LN	(Østmo, 1977; Segerberg, 1978)
LN axes[b]	39	4300–3750	LN	(Bakka and Kaland, 1971; Lomborg, 1973)
Total	**1045**			

[a] Thick-butted stone axes, thin-bladed flint axes/adzes, thick-bladed axes/adzes, thick-bladed flint axes with hollow edges, boat axes of stone.
[b] Two-sided flint axes, broad-edged flint axes.

in the succeeding periods. These are Vespestad adzes (mainly EN), Vestland adzes (mainly MNA) and Shafthole axes (mainly LN).[2]

As is evident from Table 1 and 2, the chronological resolution for the individual types of stray finds is highly variable, with the Mesolithic types having significantly longer use-periods than the Neolithic types. This means that possible demographic fluctuations during the Mesolithic have much less resolution than those of the Neolithic. To adjust for this difference, we used aoristic weight, which reflects the probability of existence of an artifact per time interval, assuming that the artifacts can equally have existed at any time in the interval (e.g. Lawrence et al., 2021; Palmisano et al., 2017). This was done by dividing the number of years in the time unit by the number of years within each period the artifacts in question could exist. For example, using time units of 100 years give an aoristic weight of 100/700 = 0.143 for EN covering 700 years (Table 2). With 144 stray finds from EN, this gives 144 × 0.143 = 20.6, which is the aoristic weight of stray finds per 100 year.

[2] 63 (also Neolithic) artifact types have been used evenly across the compared periods, and they are therefore excluded. These are: thin-butted flint/stone (TRB) axes (10), Vestland chisels (10), four-sided axes/adzes (20), rectangular, hollow-edged adzes (5), Sandshamn-adzes (4), and Vestland C adzes (14).

3.3. *Pollen-based estimates of tree cover*

To study the relationship between the applied population proxies and pollen-based estimates of tree cover, we have used REVEALS (Regional Estimate of Vegetation Abundance) within the Landscape Reconstruction Algorithm (Sugita, 2007). This model gives an improved picture of vegetation cover at the time of interest compared to pollen percentages (e.g. Hellman et al., 2008; Hjelle et al., 2015; Marquer et al., 2014). Hjelle et al. (2018) made regional vegetation reconstructions along the coast of southern Norway, covering most of the Holocene. From that study, estimated tree cover from Hordaland for the time 8200 to 3700 cal BP is presented here, to compare with archaeological data from the Stone Age. The reconstructions are based on pollen data from 27 sites (5 lakes and 22 bogs) located from 10 to 95 masl and mainly along the coast/outer fjord basin (Fig. 4). Two or more sites are combined within circles of radius 20 km in a systematic grid system, resulting in data from 11 areas. REVEALS estimated tree cover based on eight taxa (*Alnus*, *Betula*, *Corylus*, *Fraxinus*, *Pinus*, *Quercus*, *Tilia*, *Ulmus*) is shown as percentage of total vegetation cover using 23 taxa.

The pollen data were pooled into 500-year time intervals and the pollen sum included in the analysis varies between 20479 in the

Table 2
Number of artifacts within the archaeological periods representing different number of years and aoristic weight. The aoristic weight represents the probability of existence of an artifact within each 100-year period.

Period	Total number of artifacts	Number of years	Aoristic weight per 100 years	Aoristic weighted number of artifacts per 100 years
MM/LM (Stone adzes)	423	4000	0.025	10.58
MM/LM (Stone hatches)	52	1800	0.056	2.89
EN	144	700	0.143	20.57
MNA	93	600	0.167	15.5
MNB	96	350	0.286	27.4
LN	216	550	0.182	39.27

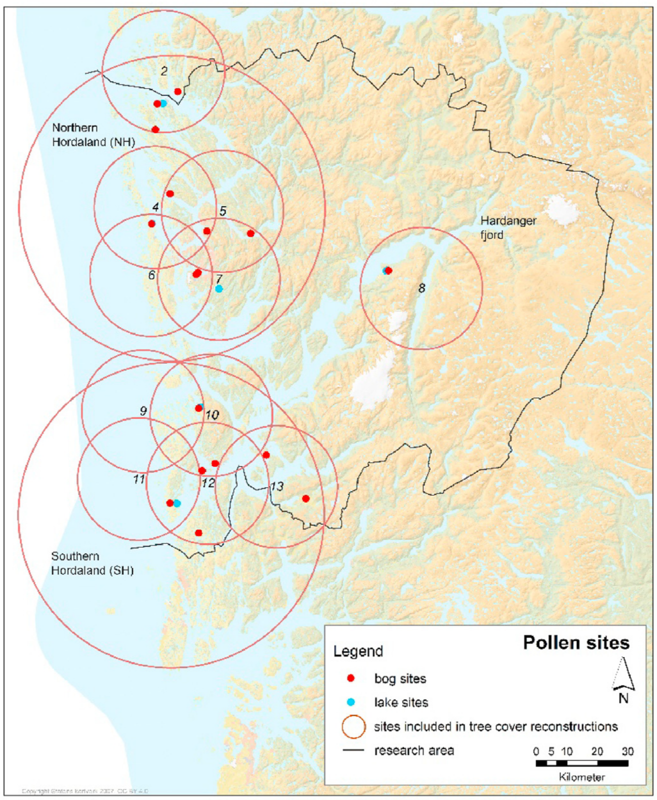

Fig. 4. Location of pollen sites included in the present study. Using a grid system of coordinates and a circle of radius 20 km, circles containing two or more pollen sites were identified and selected for land-cover reconstructions. Circle number refers to CP number in Hjelle et al. (2018). Additionally, reconstructions for sites separated in a southern (SH) and northern (NH) coastal area (coast and outer fjord basin), were carried out.

interval 7700–7200 cal BP to 61197 in the interval 4700–4200 cal BP (Table 3). Some sites are included in more than one reconstruction, resulting in a floating pattern of estimated tree cover. This floating approach makes it possible to identify the potential signal from diagrams analyzed from sites close to known archaeological sites. The more sites one includes in REVEALS, the better estimate of regional vegetation cover is given, although several sites result in high error estimates (e.g. Hjelle et al., 2015; Sugita et al., 2010; Trondman et al., 2016). To get general trends and to include more sites, new analysis was carried out for a southern (SH) and a northern (NH) group of coastal sites (Fig. 4). The program REVEALS.C.v1.5.1 (S. Sugita, unpublished) was used and the regional vegetation set to 50 km (for more details and full data set, see Hjelle et al., 2018).

Population size is one factor potentially driving changes in vegetation openness through time. Two other important factors and main challenges in relation to evaluating causes for land-cover changes are (1) Mesolithic impact versus land-use practices in the Neolithic and (2) climate change. A relationship between changes in tree cover and population size assumes that the landscape was covered by forests 8200 cal BP and that the opening-up of the landscape was caused by human impact. It also assumes that people acted similarly towards the vegetation through the Stone Age, stating that small openings mean few people and large openings mean many people.

Concerning (1) it can be argued that openings made by HFG populations and openings made by farmers have different demographic implications. Manipulation of woodlands in the Mesolithic to attract wild animals or facilitate the growth of special plants (e.g. Innes et al., 2010, 2013; Overton and Taylor, 2018; Vera, 2000; Warren et al., 2013) may have had an effect on the vegetation cover, although on a lower magnitude than what was the case after the introduction of animal husbandry and cultivation when open landscapes became a necessity. Land-cover reconstructions in different parts of Europe have shown increased openness the last 6000 years – and increasing with time – demonstrating the large effect of agriculture on the vegetation cover compared to woodland manipulation and clearing by HFG populations (e.g. Fyfe et al., 2013; Hjelle et al., 2018; Lechterbeck et al., 2014; Marquer et al., 2014; 2017; Mehl et al., 2015; Nielsen et al., 2012). It can therefore be argued that land-cover changes, at least from the latter part of the Neolithic, is a combined effect of demographic changes and agricultural land-use practices. This will be taken into consideration when discussing the results.

Concerning (2) climate is found to be the main driver of woodland composition and landscape openness prior to agriculture (e.g. Kuosmanen et al., 2018; Marquer et al., 2017). In our region, plant macrofossils and pollen-based climate reconstructions indicate decreased summer temperatures after 4000 cal BP causing a lowering of the tree limit for pine from above 800 m, to between 800 and 600 masl (Bjune, 2005; Bjune et al., 2005). The climate is therefore assumed not to be a limiting factor for tree growth in the lowland in our district for the investigated time. Our

Table 3
Number of pollen grains per time window used in the analysis. Sum pollen refer to the total data in Fig. 11a, sum SH and sum NH refer to the two datasets in Fig. 11b.

Cal BP	8200–7700	7700–7200	7200–6700	6700–6200	6200–5700	5700–5200	5200–4700	4700–4200	4200–3700
Sum pollen	27202	20479	28276	26985	26186	39408	45000	61197	60556
Sum NH	6833	5561	7350	8831	9938	24729	36585	42189	37766
Sum SH	20369	14017	20926	16116	15205	13720	4575	15124	18885

reconstructions are based on pollen data from sites below 100 m asl. By this selection, we avoid the effect of change in openness in the mountains, on reconstructions based on pollen data from high altitudes. Moreover, we assume that potential changes in climate driven land-cover in the coastal mountains during our time interval, has minor effect on the long-distance pollen transport and the proportion between arboreal and non-arboreal pollen deposition in the lowland sites included. This means that we consider potential changes in land-cover to reflect demographic or land-use changes.

3.4. Correlation between data sets

An analysis of the bivariate correlation between the variables for the interval 8000−3750 cal BP was done using the software SPSS Statistics 25.0.0.2 and Pearson's correlation coefficient. The included variables were the aoristic weight of stray finds, REVEALS estimates of tree cover for coastal areas of northern (NH) and southern (SH) Hordaland as well as the number of 200-year bins per 50-year increment.

4. Results

4.1. SPD analysis

A median value histogram of radiocarbon dates (cf. Williams, 2012:582) shows that the dates are unevenly distributed within the sequence (Fig. 5a). The very earliest phases have only a few dates, and there is a general trend towards increasing frequencies of dates over time. In addition, we present a histogram of the number of 200-year bins per 500-year interval (Fig. 5b), which seems to have a flattening effect on the peak observable at 6000 cal BP. This peak in the number of raw dates could potentially be an artificial effect of research strategies focused on the cultural transformations observed around this time and is mitigated using binning.

A raw SPD plot using all 703 dates can be seen in Fig. 6. The plot also includes a generalized shore displacement curve as well as curves based on data binned using different intervals (50, 100, and 200 years). In general, it can be stated, that the binned data on all levels reflect the major fluctuations seen in the raw data. The SPD indicates a long-term population growth over time. A very low peak at c. 10.000 cal BP is followed by a lack of dates. From c. 9000 cal BP dates start to pick up followed by a marked dip at c. 8200 cal BP. 8000 cal BP sees the beginning of a period of rising values, quite fluctuating in their distribution, but in general forming a "plateau". A smaller decrease 6300−6200 cal BP is followed by an increase to a first maximum c. 5200 cal BP and a relatively stable plateau up until c. 4400 cal BP, when a slight decrease is followed by a significant rise in date observations. The binning effect is most obvious for 6000−4300 cal BP, as noted above, as well as reducing the conspicuous spike centering on c. 7000 cal BP.

Due to the taphonomic issues with the EM/MM settlements outlined previously, dates earlier than 8000 cal BP will be omitted from subsequent hypothesis testing. It is believed that the data for this earlier period cannot accurately reflect demographic processes, but rather is a combined effect of the Tapes transgression and a well-known difficulty in obtaining samples for radiocarbon dating at earlier sites (Åstveit, 2017: 256−258). The early Bronze Age dates (Fig. 6) are also omitted from further investigations.

In Fig. 7a we have plotted the empirical SPD against a null model displaying uniform growth during the time interval 8000−3750 cal BP. This model showed a statistically significant p-value (0,001) and is therefore considered to be rejected. In this model there are two significant negative deviations during the Mesolithic, the first 7400−7300 cal BP and the second 6350−6200 cal BP. From then on, the SPD shows a fluctuating growth pattern contained within the simulated envelope until a pronounced positive deviation from the null model occurs, starting c. 4200 cal BP. We have also plotted the SPD against an exponential model (Fig. 7b). Here, the p-value is much higher (0,13876) and the null hypothesis cannot be rejected. The exponential model has a positive deviation 7000−6850 cal BP and two others c. 4000−3800. There is also a short-term negative deviation during the late Mesolithic 6250 cal BP and a long-term during the middle Neolithic 4450−4200 cal BP. Although within the confidence interval, at 5400 cal BP, towards the end of the EN, there is a marked growth in the empirical curve, which brings it up to a higher level during the MNA.

Overall, the long-term trend of the empirical SPD shows a relatively good fit to the exponential model, showing gradual and fluctuating growth, but with a particularly marked growth during the LN 4200−3800 cal BP.

4.2. Stray finds

The total number of artifacts per main period show that the Mesolithic finds make up a large share (Fig. 8a). When considering the aoristic weight, however, the Mesolithic finds is considerably lower per time unit than the Neolithic (Fig. 8b). For the Mesolithic, there are slightly more artifacts per time unit in parts of the earlier than in the later MM/LM. A marked increase in artifacts per time unit take place in the EN, followed by a reduction in the MNA. Then there is a marked growth in the number of stray finds per time unit during the MNB, with a similar result during the LN.

The geographical distribution of the stray finds (Figs. 9 and 10) also shows marked changes between the different main periods. The MM/LM finds concentrate heavily at the coast, with less artifacts found by the fjords. This trend is also valid for the EN and MNA. Compared to

he coast zone, there is a relative increase of MNB axes in the fjord/interior lowland zone, and this tendency is considerably strengthened during the LN.

4.3. Pollen-based estimates of tree cover

The geographical setting of the pollen data is shown in Fig. 4 and the REVEALS-estimated tree cover for 500-year time intervals in Fig. 11. In the earliest time interval, different tree cover is estimated for the southern and northern part of the area, both when few sites are used (Fig. 11a) and as a mean of several sites (Fig. 11b). Several tree species had arrived southern Hordaland at that time (Fægri, 1944; Midtbø, 1995) and a tree cover of c. 80% is in line with this. The same species had arrived also the northern area (Kaland, 1984; Mehl and Hjelle, 2015) and the forested landscape characteristic for the Mesolithic was established in this 500-year time interval (Mehl et al., 2015: Fig. 8). The high degree of openness indicated therefore does not reflect a northward delayed tree dispersal, but rather the openness along the outer coast and the location of the few sites included in the reconstructions, some from the vicinity of Mesolithic sites (cf. Hjelle et al., 2018). This indicates that natural local conditions cause differences in tree cover between areas, but also that vicinity to a settlement site may affect the tree cover, as reflected in the small temporal fluctuations estimated within an area. From 7700 to 5700 cal BP, all areas, with one exception 7700−7200, have 75−90% estimated tree cover. The highest tree cover, >90%, is estimated in the inner fjord zone. For all areas, this may reflect the general tree cover in periods with low population density.

In the interval 5700−5200 cal BP (mainly EN), a first minimum in tree cover is reached in most coastal areas, whereas high tree cover is still indicated in the inner fjord area (area 8). The decreasing trend in area 2, may reflect the marked increase in sedentary settlement during the EN in the local "hot-spot" area by

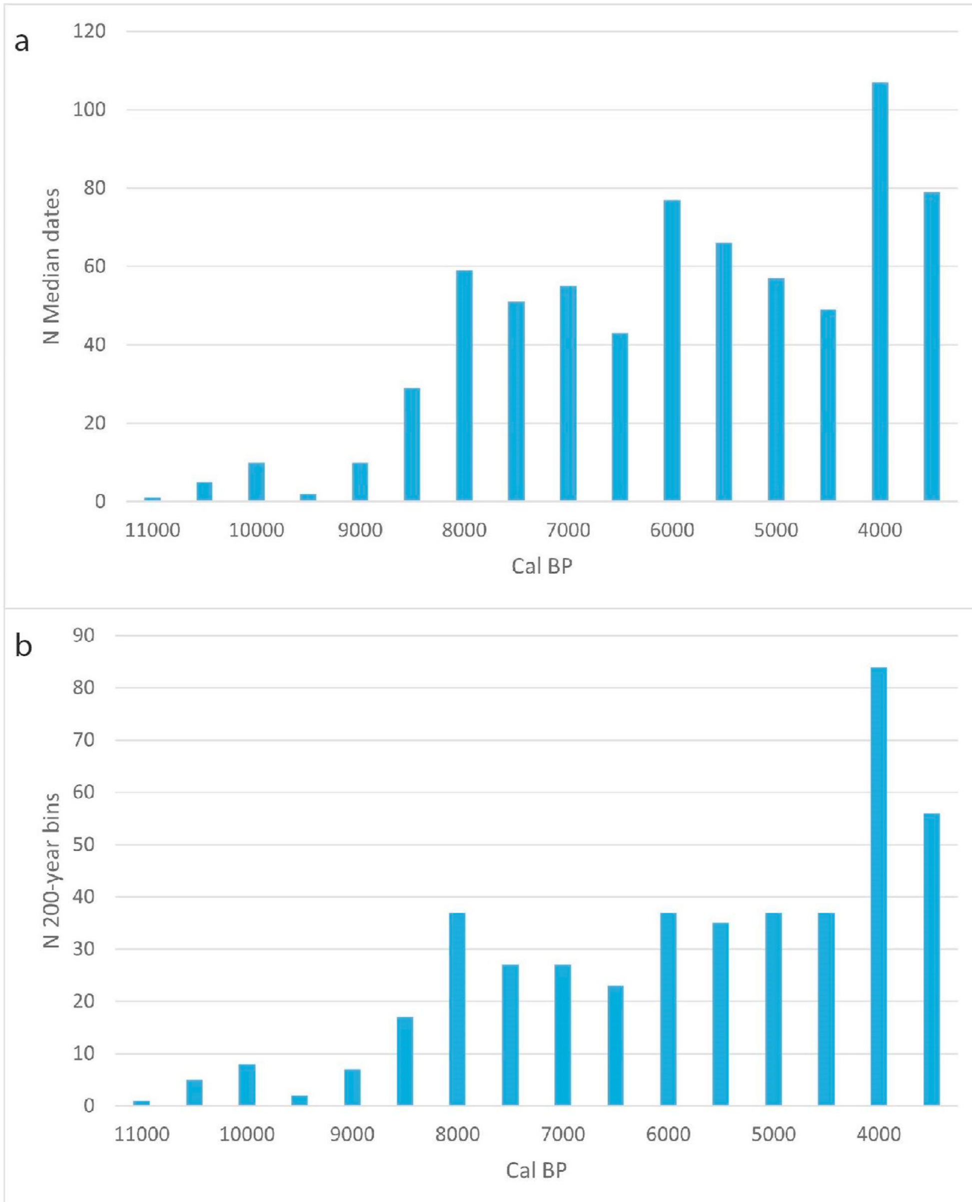

Fig. 5. (a) Histogram of the 703 dates (median values) in blocks of 500 years, and (b) 200-year bins per 500-year interval.

Kotedalen (Bergsvik, 2001; Olsen, 1992). The lowest tree cover, 60%, is estimated for area 7, including both the large lake Kalandsvatn and a small site close to a settlement site. Using only the data from Kalandsvatn situated in some distance from the coast and less influenced by local vegetation and activity than smaller sites, the estimated tree cover show fluctuations between c. 82 and 86% (Mehl and Hjelle, 2015). The trend of forest clearance in EN in nearly all coastal areas in contrast to more than 90% forest cover in the inner fjord zone is probably connected to demographic changes and may also indicate some first farming attempts.

5200–4700 cal BP (EN/MNA) reflects a new period with increased tree cover in several areas, with estimates of more than 90% in the fjord area in the south (area 13). However, also this period shows variations and area 8 by the Hardangerfjord (Mehl and Hjelle, 2016), as well as coastal areas in the southern part of the district (areas 11 and 12), all indicate a steady decrease in tree cover starting in this period.

4700–4200 cal BP (mainly MNB), the tree cover is estimated to between 66 (area 12) and 90% (area 13), further reduced to between 40 (area 7) and 86% (area 10), 4200–3700 cal BP (mainly LN). This large variation in LN compared to earlier periods, probably reflects differences in demography (and economy) within the study area. The effect of local sites on the reconstructions are also clearly visible. A marked opening-up of the landscape is indicated for area 8, where local forest clearance took place in LN (Mehl and Hjelle, 2016), in contrast to the high tree cover estimated for area 10, where the main forest clearance took place in the Bronze Age (Overland and Hjelle, 2009).

The tree cover estimated based on the southern (SH) and northern (NH) groups of coastal sites respectively, show both similarities and differences (Fig. 11b), but overlapping estimates within one standard deviation except for 8200–7700 cal BP. In this period the tree cover is higher in the southern than in the northern area, as discussed above. Although with overlapping error

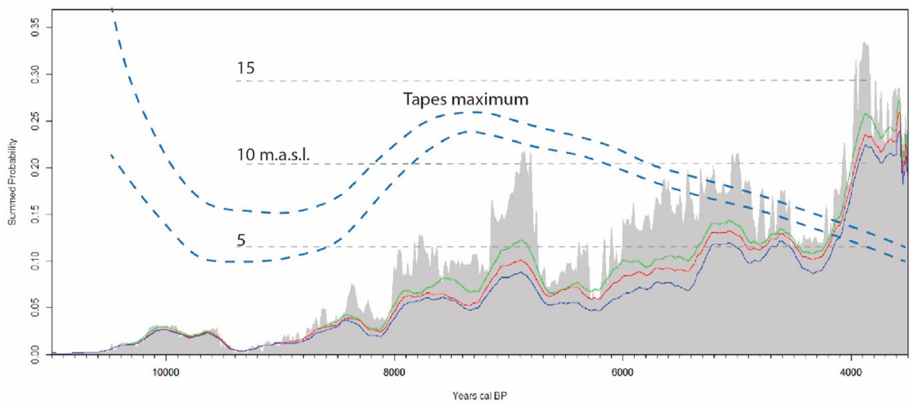

Fig. 6. The 703 dates and summed probability distribution with (non-normalized) dates binned at 50 (green, upper), 100 (red, middle) and 200 (blue, lower) years. ΔT = 62. Included are also the regional shoreline displacement curves, generated using Sea Curve v1 (Kaland, 1984; Lohne, 2006; Romundset, 2005; Vasskog, 2006). The two curves displayed cover the variation in shore displacement rates of northernmost (upper) and southernmost (lower) Hordaland, respectively. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

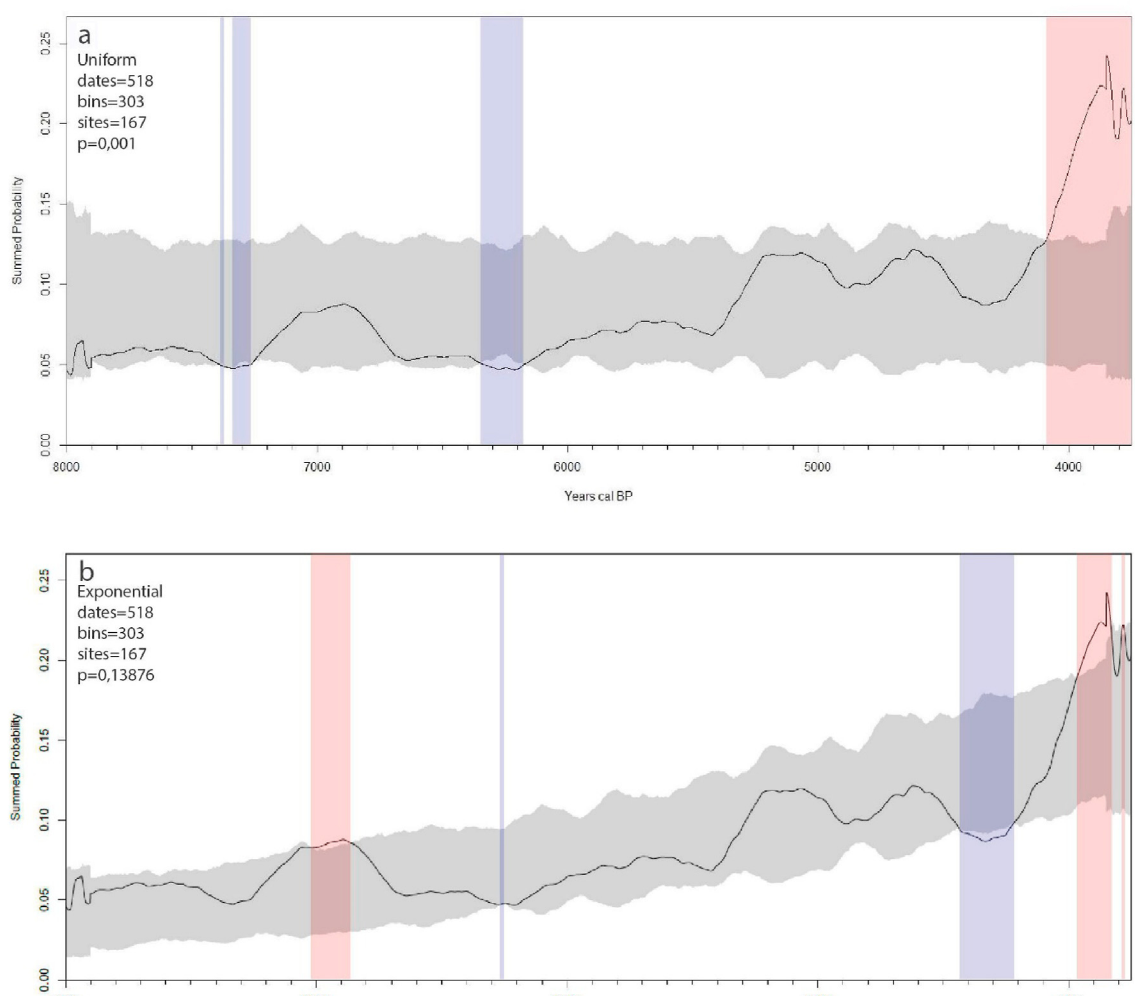

Fig. 7. Summed probability distribution of binned (bins = 200 years) radiocarbon dates superimposed on uniform (a) and exponential (b) population models in the time interval 8000-3750 cal BP. Nsim = 1000. Dates are calibrated using intcal20, and not normalized. ΔT = 62.

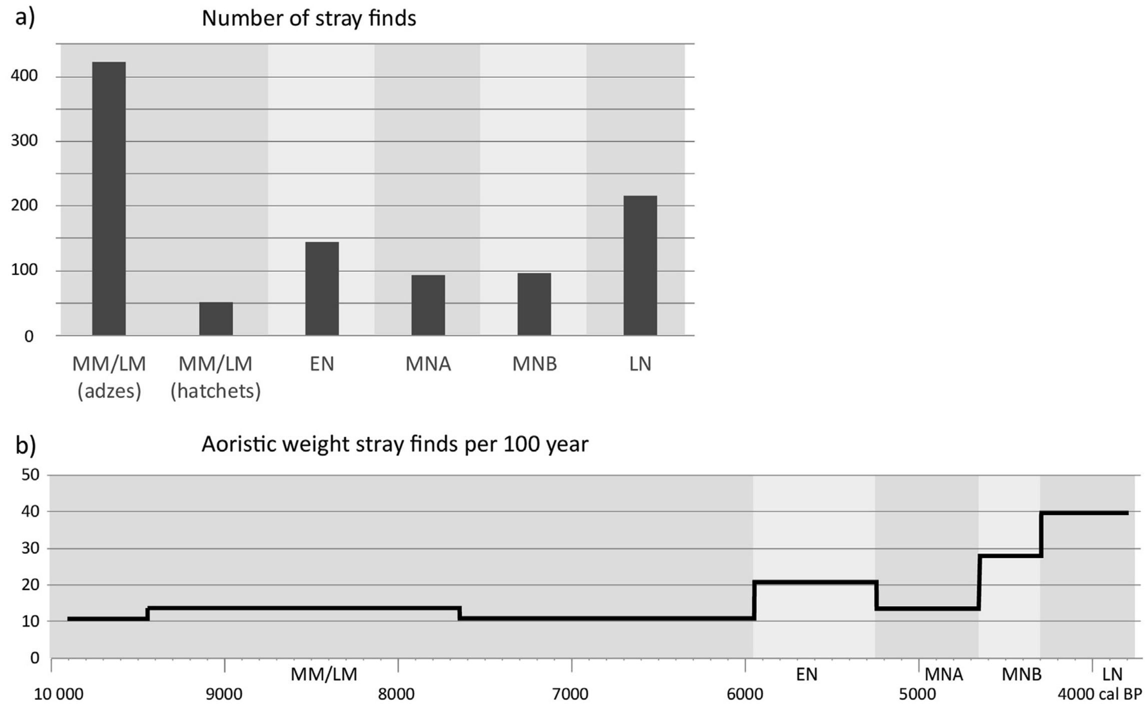

Fig. 8. Mesolithic and Neolithic stray finds in Hordaland. (a) total number of stray finds (b) aoristic weight of stray finds per time unit (100 years).

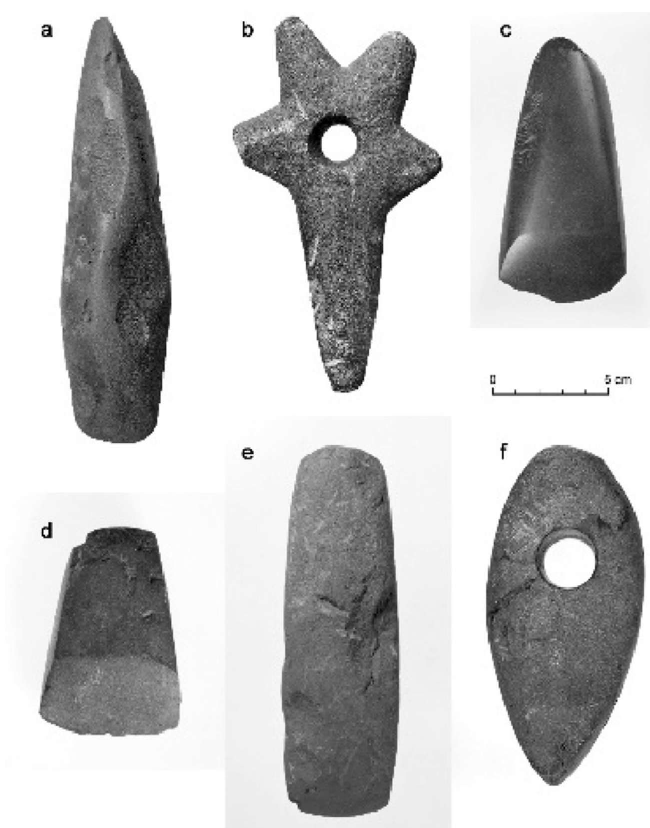

Fig. 9. Examples of stray finds from Hordaland. (a) MM/LM chubby stone adze (museum no. B7368), (b) MM/LM star-shaped hatchet (B10970), (c), EN Vespestad adze (B13452), (d) MNA Vestland adze (B7258), (e) MNB thick-butted stone axe (B14728), (f) LN shafthole axe (B11192). Photos: University Museum of Bergen. Printed with permission.

estimates, some overall trends in the data may be indicated. High tree cover is estimated until EN, time interval 5700–5200 cal BP, when c. 70% tree cover is estimated for both areas, supporting the large variation but general decreasing trend in all the smaller areas. In the southern part, the tree cover has a weak increasing trend from that minimum, whereas an increase, followed by a marked decrease is seen in the north, reaching a minimum of 65% 4200–3700 cal BP.

In general, the results show two periods with opening-up of the forest: 5700–5200 cal BP and 4200–3700 cal BP, the latter coinciding with increase in SPD and stray finds. In the inner fjord area, the first reduction in tree cover took place 5200–4700 cal BP, followed by the same marked decrease as by the coast 4200–3700. In LN, and keeping to botanical data, both anthropogenic indicators in pollen diagrams and plant macro remains from archaeological sites document that agriculture was established (Hjelle et al., 2006; Halvorsen and Hjelle, 2017; Overland and Hjelle, 2009). The estimated tree cover reflects population expansion into new regions, but also forest regeneration in areas earlier occupied by HFG people, now abandoned. Immigration of new groups of people is also possible. In the first period 5700–5200 some anthropogenic indicators in pollen diagrams indicate that the spread of agriculture had reached Hordaland (Hjelle et al., 2006, 2018). However, the strong impact on the tree cover surrounding coastal sites may also reflect vicinity to the stable EN/MNA settlements documented in the archaeological record. Increased sedentism (Bergsvik, 2001) with need for firewood and higher utilization of forest mammals (Hufthammer, 1992), may have contributed to opening-up of the landscape, either alone or in combination with low-level agriculture (Bergsvik et al., 2020).

4.4. Correlations between SPD, stray finds, and vegetation cover

Three correlation coefficients are flagged as significant, on the two-tailed level, in the analysis (Table 4, Fig. 12). There is a moderately strong negative correlation (−0,46) between stray finds

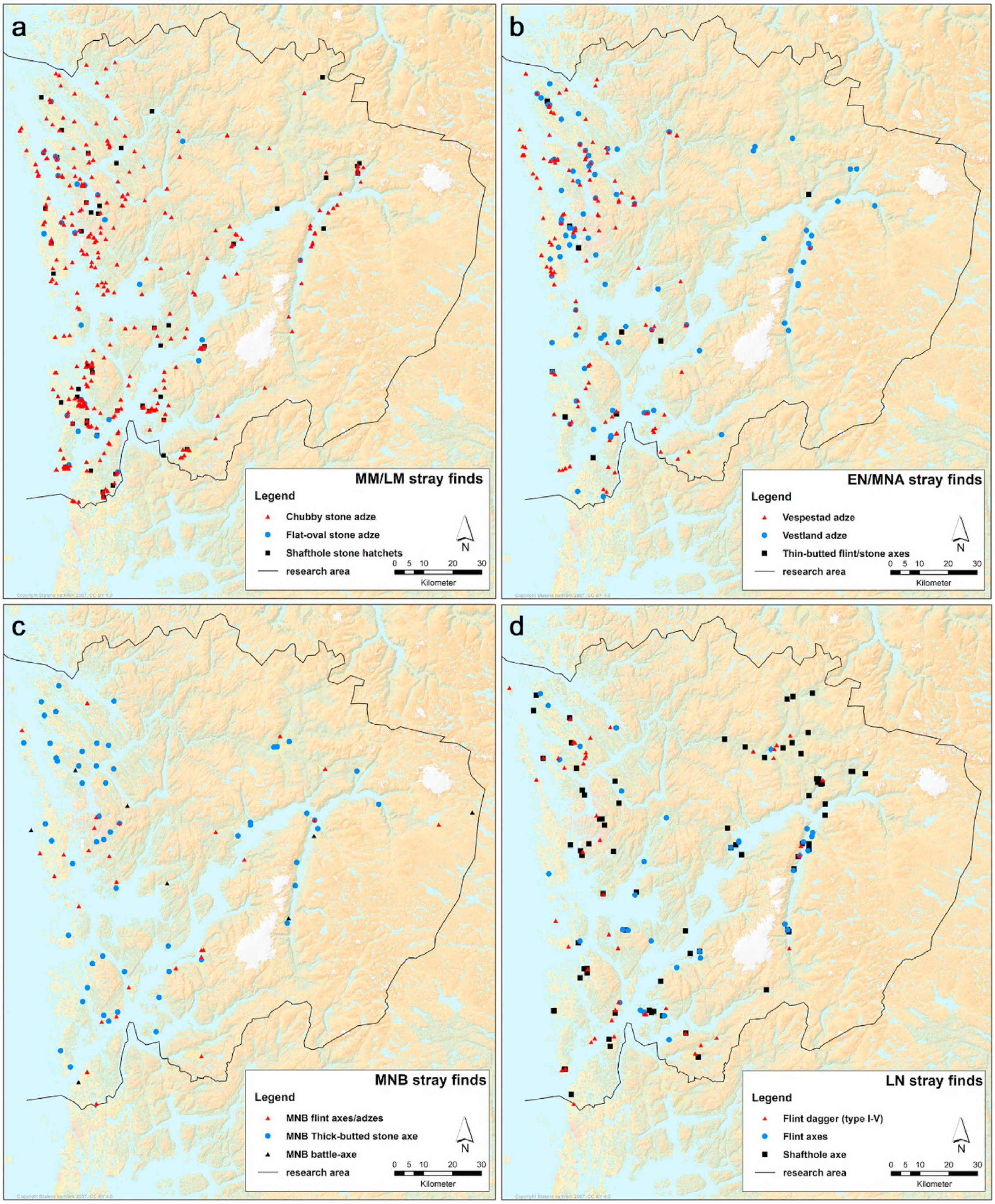

Fig. 10. Distribution of stray finds in Hordaland. (a) Middle/Late Mesolithic, (b) Early Neolithic/Middle Neolithic A, (c) Middle Neolithic B, (d) Late Neolithic.

and tree cover in northern Hordaland, a weak negative correlation (−0,29) between tree cover in northern Hordaland and the number of 200-year bins, as well as a weak positive correlation (0,41) between the number of stray finds and 200-year bins. The estimated tree cover of southern Hordaland does not correlate with any of the other data, probably due to a more scattered distribution of small pollen sites, partly at longer distance from archaeological Stone Age sites, than is the case for northern Hordaland (compare Figs. 2, 4 and 10). The correlation coefficients in general reflect, that although the amount of stray finds on a general level covary with the number of C14-dates, increasing over time, there are notable discrepancies, resulting in such low correlation coefficients. There is also a certain tree cover decrease, as the number of stray finds and bins, i.e. human activity, increase.

5. Discussion

In a general perspective, our study has revealed a pattern of dated contexts increasing over time, which coincides with an increase in the number of chronologically diagnostic stray finds. The correlation analysis confirms this pattern by the significant relationship between

radiocarbon dates and stray finds. Moreover, it indicates that human impact was an important driver for vegetation change, at

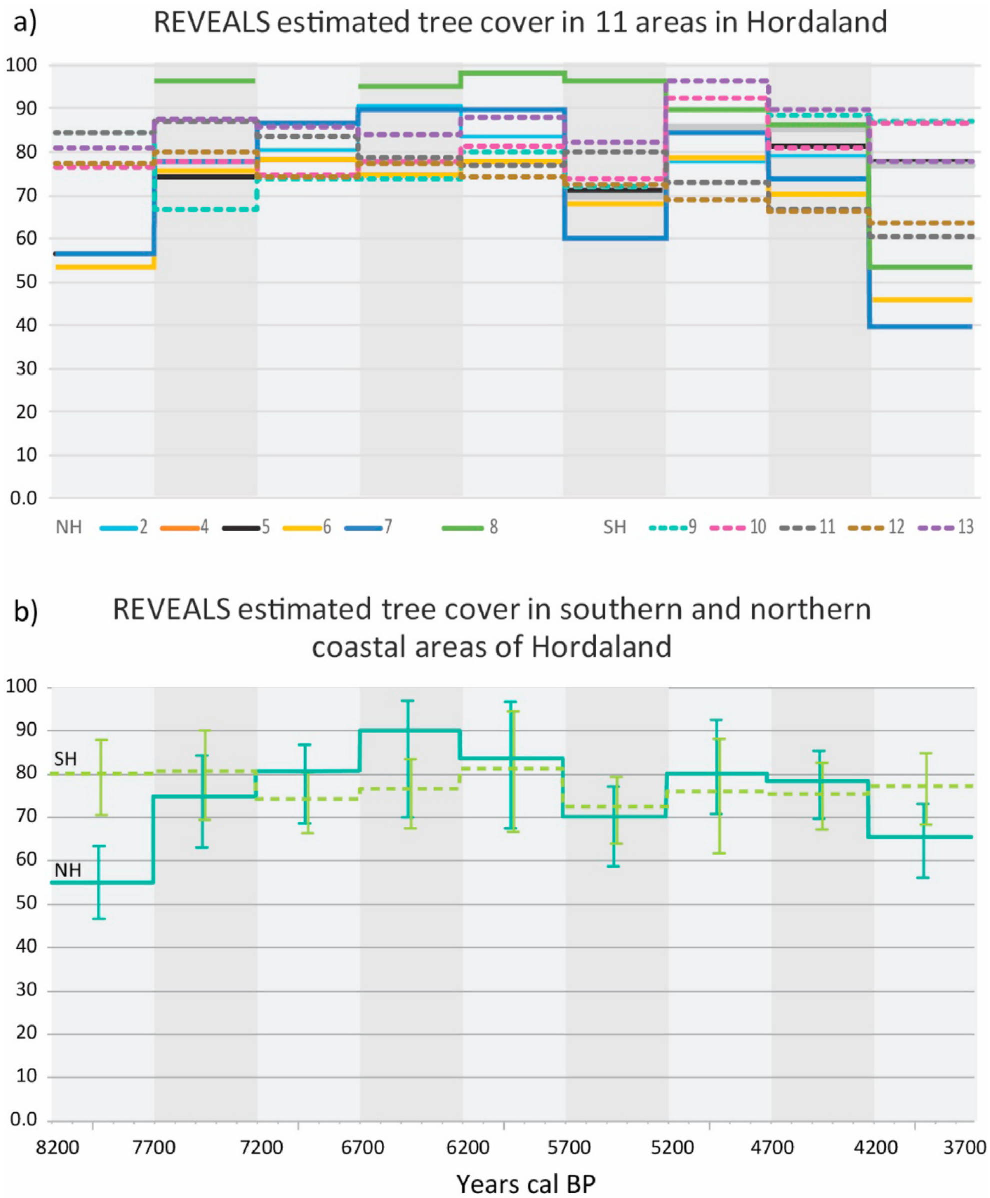

Fig. 11. Estimated tree cover for different areas in Hordaland (see map, Fig. 4) for 500-year time intervals between 8200 and 3700 cal BP using REVEALS (Sugita, 2007). (a) Reconstructions from 11 areas modified from Hjelle et al., (2018: Fig. 2, more details in Appendix S3) and (b) Estimated tree cover and their error estimates for coastal areas of northern Hordaland (NH) and southern Hordaland (SH).

Table 4
Pearson's correlation coefficients for the time interval 8000–3750 cal BP.

	Stray finds	Tree cover (NH)	Tree cover (SH)	200-year bins
Stray finds	1	**−0.46**[a]	−0.14	**0.41**[a]
Tree cover (NH)		1	−0.8	**−0.29**[a]
Tree cover (SH)			1	−0.06
200-year bins				1

[a] Correlation is significant at the 0.01 level (2-tailed).

least near the settlement sites, and by the consistent pattern revealed from the LN. On the face of it, the data thus seems to be consistent with the idea of general population growth in the region between 8000 and 3750, but there still is room for discussion on certain points.

It is interesting to note that the SPD graph shows a marked decline before c. 8000, already c. 8200 cal BP, which is contemporary to the postglacial cooling event (e.g. Eldevik et al., 2014; Kobashi et al., 2007), perhaps also to the tsunami c. 8100 cal BP (Bondevik et al., 1998). However, although there might be a connection, the taphonomic problems (flooding of sites during the Tapes transgression) is probably the most important reason for the

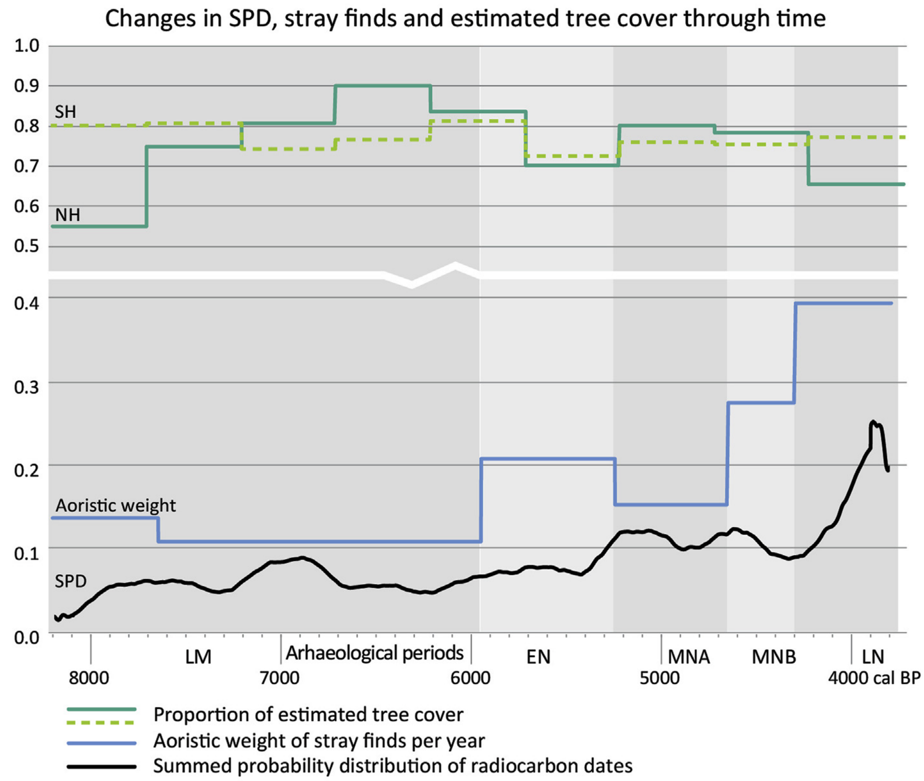

Fig. 12. Combination diagram showing the two demographic proxies, summed probability distribution of radiocarbon dates in 200-year bins and aoristic weight of stray finds, together with REVEALS estimated tree cover in Northern and Southern Hordaland. Note different vertical scale in the top and bottom of the figure.

lack of C14-dates from this period, and it masks possible other factors (Fig. 6). One could argue that the taphonomic problems before c. 8000 cal BP should also affect the distribution of the stray finds, but this does not seem to be the case, as the shaft hole hatchets show a somewhat higher number than the average use of adzes during the MM/LM periods. Still, many of these hatchets may have been placed ritual deposits some distance from the contemporary shorelines (Skår, 2003), and might therefore not have been as affected by the transgression as were the residential sites.

Previous interpretations of Stone Age subsistence and settlements suggest that, from c. 8000 cal BP and throughout the Mesolithic, the populations in western Norway had relatively stable semi-sedentary subsistence-settlement patterns within social territories and they utilized a variety of fish and mammal species (Bergsvik and Ritchie, 2020; Hufthammer, 1992; Olsen and Alsaker, 1984). As is indicated by the spatial distribution of C14-dates as well as stray-finds (Figs. 2 and 10a), their main activity areas were at the coast.

From c. 8000 cal BP our SPD data shows a fluctuating pattern during the late Mesolithic, where some features warrant a comment. The peak c. 7000 cal BP is conspicuous and one possible explanation is that this reflects an increase in sedentism and a subsequent clustering of population in certain attractive coastal areas during this period. However, it can also be related to the fact that the Tapes maximum occurred just around this point in time (Fig. 6). This led to a concentration of shore bound sites at the same spot for several hundred years, and therefore better visibility of sites, leading to more excavations, and more radiocarbon samples taken. During 6900–6250 cal BP the empirical SPD decreases, which could be the result of sites being less visible again, considering the isostatic uplift and a new regression leading to sites being moved downwards in the terrain. Another possibility is that the reduction of dates indicate population decline during this period. 6700–6200 cal BP is also the period with the highest tree cover estimated by the coast. The stray finds unfortunately cannot contribute information on this point due to the long use period of the Mesolithic adzes. When looking at similar results in Mesolithic *eastern* Norway, SPD and site counts show stable patterns, indicating that a population of a certain size was established already c. 10.000 cal BP and that there was a long-term growth with fluctuations after that (Solheim and Persson, 2018; Solheim, 2020). Further north, in northern Norway and northwest Finland, the tendency is also that of gradual increases (with minor troughs) in the number of dates in the SPD between c. 10.000 and 6000 cal BP (Jørgensen, 2020; Tallavara and Pesonen, 2020). The slightly different trajectories in the different regions suggest that even if they were all marine oriented HFG populations, they must have operated relatively independently of each other and were probably affected differently by environmental changes as well as cultural factors.

5950 cal BP marks the transition to the EN, which in western Norway is characterized by increasing HFG coastal sedentism, increasing diversity in the subsistence base (more hunted and fished species), the possible introduction of low-level agriculture, several technological and typological changes (new adze types, projectile point types, fishhook types, new lithic reduction technologies, a number of new locally quarried lithic raw materials and from the latter part of the EN locally produced pottery). There were also imported goods such as Funnel Beaker (TRB) axes and pottery (Bergsvik, 2001; Bergsvik et al., 2020; Hjelle et al., 2006; Nærøy, 1993; Olsen, 1992).

The changes observed in our study are, however, equivocal. The

SPD shows a minimum in the graph two-three centuries before the transition, which is followed by a very slow growth during most of the EN until c. 5600 cal BP, followed by a small decrease before a new rise at the end of EN. In contrast to the SPD, and compared to the MM/LM, the EN stray finds – also in this period mainly found at the coast (Fig. 10b) – show a marked increase. One factor that may have caused some of the divergence between these data types is that surveyed EN residential sites are often dated by the presence of the raw material rhyolite, which was mainly used during the EN and was extensively applied for lithic tools in Hordaland (Nærøy 1993; Olsen 1992). C14-dating is often not considered necessary for this reason, possibly leading to an under-representation of dates to the EN compared to the periods before and after. As seen from Fig. 4, EN is a period of intensive activity at a few well-dated sites. Furthermore, the palynological evidence shows that a marked reduction in tree cover took place 5700–5200 cal BP, suggesting that a population growth may have taken place. At the same time, anthropogenic indicators are present (Hjelle et al., 2006), supporting that this was a humanly induced reduction in tree cover on a regional scale. This indicates that the different changes that characterized the LM-EN transition in western Norway possibly were accompanied by a certain growth in the population, preceded by a decline in the Mesolithic population, as indicated by the significant deviation at 6300–6200 cal BP.

In this context it is also important to look at the development in adjacent regions, where similar, but also different patterns emerge. In contrast to the Mesolithic, where the data showed somewhat different trajectories in the different regions, there are almost contemporary peaks in the SPDs during the early Neolithic: in eastern Norway c. 5800 and in northwestern Finland and northern Norway c. 5700 cal BP (Jørgensen, 2020; Nielsen et al., 2019; Solheim and Persson, 2018; Tallavaara and Pesonen, 2020). The contemporaneity in demographic growth in all these areas – although possibly less so in western Norway – suggest that they were interconnected, either because of particularly productive natural environments or that certain cultural factors favored a population increase. One such "cultural factor" may have been the emergence of the Funnel Beaker complex and the transition to agriculture, which took place in southern Scandinavia around the same time, and which was accompanied by a population boom in that area (e.g. Hinz et al., 2012; Shennan and Edinborough, 2007; Shennan et al., 2013). Agriculture seems to have been introduced at a low level during the EN and MNA in eastern and western Norway (Bergsvik et al., 2020; Hjelle et al., 2006, 2018; Reitan et al., 2018; Wieckowska-Lüth et al., 2017), but not in northern Norway and Finland. Nevertheless, the important social and economic changes that took place in southern Scandinavia may still have had extended effects on these northern regions, for example as a result of increased mobility/migrations and exchange (e.g. Zvelebil, 2006; Zvelebil, 2008) which triggered population increases also there.

By the end of the EN, c. 5400 cal BP, there has been a marked growth in the SPD, and the graph displays a relative stability for 6–700 years, throughout MNA, and until the transition to the MNB c. 4650 cal BP. The stray finds show a different tendency, as the number of MNA Vestland adzes are much lower per time unit than the number of EN Vespestad adzes. As pointed out above, however, the Vespestad- and Vestland adzes are chronologically overlapping during the EN/MNA transition, a factor that might reduce somewhat this difference. The palynological data show increased tree cover in several coastal areas 5200–4700 cal BP (MNA), which could in fact indicate demographic differences within the district (cf. Hjelle et al., 2018; Mehl et al., 2015). A more detailed picture for the development within EN/MNA is given by Mehl and Hjelle, (2015), showing a minimum of regional tree cover 5600 cal BP, followed by a peak c. 5400 and somewhat lower and constant estimates until 4800, when a gradual decrease towards a new minimum 4400 cal BP started. For the late EN and the MNA the multi-proxy data is therefore equivocal.

It appears that the emergence of the Funnel Beaker complex in southern Scandinavia displays a boom followed by a bust in the SPD (e.g., Shennan et al., 2013; Warden et al., 2017), even if the development in that area was regionally diverse (Hinz et al., 2012; Torfing, 2016). The SPDs from eastern and northern Norway and Finland also show marked reductions after c. 5600 cal BP (Jørgensen, 2020; Solheim and Persson, 2018; Tallavaara and Pesonen, 2020). Compared to these patterns, the development during the late EN and MNA in western Norway indicated by the SPD and the palynological data stands out as particularly stable in an interregional context.

4300 cal BP dates the transition to the LN in western Norway, and the MNB period (starting c. 4650 cal BP) is a phase of transition, in which the populations increased their contact networks towards the south and east, and when agriculture gained importance at the expense of hunting and fishing (Bergsvik et al., 2020; Hjelle et al., 2006; Olsen, 2009, 2013). Our data reflect these changes, but they are again equivocal in terms of the demographic implications. The SPD shows a decrease in the graph starting around the transition to the MNB and ending at a low point c. 4300 cal BP. This development is, however, largely contradicted by the stray finds, which instead show an increase during this period. The data on tree cover shows either quite stable conditions or deforestation, supporting that new areas were taken into use. The land-cover reconstructions based on one large lake (Mehl and Hjelle, 2015), showed decreased tree cover from 4800 to 4400 cal BP, followed by a small increase at the MNB/LN transition.

This divergence in the MNB data is hard to explain, however, some source critical factors may be relevant for SPD as well as stray finds and vegetation reconstructions. Concerning the SPD, it is possible that HFG sites from this period are somewhat underrepresented in terms of radiocarbon dates. They are stratigraphically always in the (often disturbed) upper levels at sites, making it problematic to use the traditional C14-method with large samples for dating, and possibly resulting in fewer samples taken even if the layers/sites are there (but see Olsen, 2009 for a different view). As noted previously, it is also a question whether the quantitative distribution of the MNB stray finds can be directly compared to those of the EN/MNA. As is indicated by the distribution map (Fig. 10c), the main bulk of the MNB stray finds have probably been deposited close to agricultural interior or fjord settlements, potentially leading to them being more easily recovered than older HFG artifacts. As such, they may be over-represented in the graph. These two factors may somewhat even out the differences between the diverging results. Nevertheless, the differences remain problematic concerning the overall demographic implications of the MNB data although the estimated tree cover does not indicate lower activity or demographic decline during this time. The included pollen data are both from the vicinity of HFG sites and from areas more favorable for agriculture. This may explain the variation in landscape openness estimated for MNB and support an uneven sampling of radiocarbon dates resulting in the diverging results based on archaeological data. The smoothing out of regional differences when combining the pollen data in SH and NH (Fig. 11b), may also indicate that the results, whether it is REVEALS reconstructions or SPD, is a matter of spatial scale. One should, however, keep in mind that our SPD data reflects 200-year time intervals, whereas the time scales both for the palynological data and the stray finds may be on too coarse a scale to catch changes within MNA or MNB, indicated by the SPD-data.

The LN is characterized by significant changes in the cultural repertoire (e.g., introduction of bifacial technology, several new artifact types, new architectural solutions with primarily southern Scandinavian origin), and radical changes in the subsistence base and settlement pattern (transition from a mainly foraging to mainly farming economy) (Hjelle et al., 2006; Prescott, 1995). During this transition, the SPD shows a remarkable growth, starting c. 4300 cal BP. The stray finds also show marked growth patterns that co-vary with these changes, and they are found in equal quantities in the fjord areas as at the coast (Fig. 10d), although the LN C14-dates are mainly from coastal sites (Fig. 2). De-forestation, especially in the fjord area, is shown by the palaeobotanical data (Fig. 11). Nevertheless, also here, some source critical problems need to be considered. The challenges just mentioned concerning the MNB stray finds are relevant also for the LN material, the majority of which have been found in areas favorable for farming in prehistory as well as today. It can also be argued that the radiocarbon dates are somewhat more numerous during the LN because of differences in sampling contexts and strategies. Almost all surveyed and excavated sites older than the LN are residential sites. Even if radiocarbon dates are usually applied, this need not always be the case, as LM/EN/MN sites can also be dated by artifacts and references to their typological/technological frameworks. In contrast, LN sites are mainly agricultural layers (fields or clearances by fire/for grazing). These layers are usually just documented in sections or by means of machine top-soil stripping. Such investigations seldom produce datable artifacts, leaving radiocarbon sampling as the only dating method. This may have led to an overrepresentation of radiocarbon dates compared to the number of sites during the LN. Their agricultural origin is well documented (e.g. Halvorsen and Hjelle, 2017) and their presence may indicate that agriculture rather than population growth caused the opening-up of the landscape in LN. Nevertheless, even if these factors are considered, the quantitative and qualitative changes taking place during the transition to the LN are too clear to be ignored. They probably indicate a major growth in population, and most likely, this growth was a part of the radical cultural and economic changes that took place in western Norway in this period. This is confirmed by the palynological data from southwest Norway, where marked opening-up of the landscapes are found (Hjelle et al., 2018). In most of the adjacent regions, a marked increase in the number of radiocarbon dates also starts 4300–4200 cal BP (Jørgensen, 2020; Nielsen et al., 2019; Solheim and Persson, 2018), indicating population growth also there.

6. Conclusions

In this first attempt to a demographic study in western Norway our main hypothesis was that two major “big” transformations during the Stone Age of northern Europe, which took place c. 5950 and 4300 cal BP, were accompanied by demographic changes. To test this hypothesis, we applied an interdisciplinary approach with two population proxies from the district Hordaland: SPD of radiocarbon dates, and quantitative and spatial distribution of stray finds. These were compared to pollen-based landscape reconstructions. Generally, the data indicates a long-term population increase and a positive correlation between SPD and stray finds were found, as well as a negative correlation between these and tree cover in northern Hordaland. The analysis clearly supported the hypothesis of a change c. 4300, as there were marked increases in the number of radiocarbon dates as well as in the number of stray finds, and a deforestation took place. It is less certain whether the transformation c. 5950 was connected to population increase. On the one hand it is characterized by a marked growth in the number of stray finds, and a deforestation took place after 5700 cal BP, on the other, the SPD is slowly increasing but relatively stable during the LM-EN.

Our proxies indicated that there were demographic fluctuations before as well as between these events. Our SPD database has reliable data only from c. 8000 cal BP, however, from then on and until c. 6200 there was a fluctuating tendency in the number of dates, but with a peak c. 7000. It is not clear whether this peak and the subsequent decline is a result of sampling biases or other factors. Interesting is also the increase in the number of radiocarbon dates during the late part of the EN and relative stability during the MNA, which stands in contrast to the developments in adjacent regions, where the SPD troughs are much more marked. This could mean that populations were kept at a higher level during the late EN and MNA than during the early/middle EN. This scenario is, on the other hand, not clearly supported by the stray finds, which instead could indicate a population reduction during this period, nor by the tree cover, which is higher at the EN/MNA transition than earlier in EN. For the MNB, the trend is the opposite: while the SPD indicates a population reduction, the stray finds show a marked growth and pollen data indicate variations within the study area. These diverging results for the Mesolithic as well as the Neolithic warrant methodological cogency and interpretative caution. To the very least they strengthen the argument that SPD of C14-dates (or any other population proxy) should preferably be applied in combination with other proxies to produce reliable results to Stone Age demographic studies. Such studies are currently being carried out in western Norway. These new investigations are performed on different geographical scales, include new proxies, and investigate more extensively the human-environmental dynamics.

Credit author statement

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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