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The Stone Age Conference in Bergen 2017

Dag Erik Færø Olsen (ed.)

UNIVERSITY OF BERGEN

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Preface

This anthology is based on contributions presented as part of *The Stone Age Conference in Bergen 2017 – Coast and Society, research and cultural heritage management*. The conference was co-organized by the Department of Archaeology, History, Cultural Studies and Religion (AHKR) at the University of Bergen and the Department of Cultural History at the University Museum of Bergen (UM). The organizing committee included Dag Erik Færø Olsen (leader) and Tina Jensen Granados from AHKR, together with Leif Inge Åstveit and Knut Andreas Bergsvik from UM.

The Stone Age Conference in Bergen 2017 was the third instalment of the "Stone Age Conference" series to be organized in Norway. The first conference was held in Bergen in 1993 (Bergsvik *et al.* 1995) and the second in Molde in 2003. The purpose for the 2017 conference in Bergen was to gather archaeologists with common interest in the Norwegian Stone Age and from all parts of the national Stone Age community. Several prominent research communities exist in Norway today and representatives from all University departments and from the majority of the County Municipalities was gathered to share current results and to discuss common issues and strategies for future research.

Since the last conference in 2003, the cultural heritage management in Norway has made large quantities of new archaeological data accessible for research. Such extensive new data has provided new methodological and theoretical challenges and opportunities which is reflected in the scope of research published within the last 20 years.

The Stone Age Conference in Bergen 2017 wanted to reflect the new empirical, theoretical and methodological diversity, and to highlight how these developments could be integrated into the cultural heritage management and within future research. The conference was structured by current themes and approaches and divided into five main sessions (including a poster session) and seven session themes (see Sessions and papers at the end of this volume).

An increasing association with the *natural scientific approaches* was one important theme of the conference focusing on research on climate change, aDNA and new and improved methods for analysis and dating. Related to this was the general theme *technology* were studies on raw material and technological studies are used in mobility- and network analysis.

Managing and utilizing the large quantities of data generated over the last two decades was the basis for the themes *demography* and *subsistence changes*. The theme *methodological developments* included increasing digitalization and how this is used in rescue archaeology, with challenges and new possibilities. The conference also wanted to explore aspects of *ritual communication* where various forms of expressions, such as rock art, could elaborate and increase our understanding of several of the other main themes mentioned.

During the three days of the conference a total of 46 15 minutes presentations addressed various topics and aspects within the seven session themes. All sessions were led by session leaders and three of the conference sessions were introduced by key note speakers.

After the conference, it was decided to publish an anthology, inviting all participants to contribute including the poster participants. The publication was to be in the University of Bergen Archaeological Series, UBAS, and with Dag Erik Færø Olsen as editor of the anthology. Ten papers were submitted from all the sessions and is representative of the topics presented and discussed during the three-day conference. The papers included in this volume are organized mainly geographically starting with Northern Norway moving southwards.

Kenneth Webb Vollan focuses on housepit sites in Arctic Norway using radiocarbon dates for distinguishing reuse or occupational phases. He presents a method for analysing dates following the Bayesian approach and shows that the housepits were reused to a much larger degree than previous acknowledged.

Skule Spjelkavik and *Axel Müller* explores similar topics in their paper about quartz crystal provenance. By using laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) they were able to compare debitage from the Early Mesolithic settlement site Mohalsen I at the island Vega with samples from 19 known sources in Norway. This is especially interesting since there are no known quartz crystal occurrences at Vega and was consequently brought from the main land or other areas. This study shows the potential for using this method, even though no clear parallel to the Mohalsen debitage could be identified in the analysed material.

Jan Mangerud and *John Inge Svendsen* explores colonization processes from a geological perspective. They document how an ice sheet margin presented a physical barrier across the Oslofjord preventing human immigration until the onset of the Holocene, providing an interesting backdrop for discussing aspects of colonization processes in the Early Mesolithic.

Arne Johan Nærøy discusses the use of tools and behaviour patterns based on use-wear analysis of quartz assemblage from the site 16 Budalen in Øygarden, Hordaland County. He is able to distinguish two individuals operating at the site suggesting spatially segregated work operations. Nærøy shows through this study the potential for functional analysis of lithic material from settlement sites.

Astrid Nyland, Kidane Fanta Gebremariam and *Ruben With*'s contribution represents both the new technological and methodological developments and the interdisciplinary nature of archaeology today. This paper explorers the potential for using pXRF for regional provenance analysis of greenstone adzes in western Norway. This study revisits an older interpretation of the division of this region into two social territories in the Middle and Late Mesolithic. The results show that the method is robust and well suited for studying green stone and the authors can also largely confirm the original interpretations based on distribution networks of Mesolithic adzes.

Birgitte Skar discusses the early postglacial migration into Scandinavia based on aDNA studies on two Early Mesolithic Norwegian skeletons. Skar's results confirms the recent interpretation of a second migration into Norway from the Northeast thus contributing to the overall narrative of the colonization of Norway.

Almut Schülke revisits the topic of Mesolithic burial practises in Norway based on new data from recent excavations. Schülke highlights that human remains are often found at settlement sites, opening for discussions of various relationships between the living and the dead and human-nature engagement.

Krister Eilertsen presents results from an excavation of an Early Neolithic hut in Rogaland, Southwestern Norway. He discusses classical interpretative challenges where the lithic material and ^{14}C-datings are not comparable. Eilertsen emphasise the importance of not dismissing difficult results but rather try to find an answer to the differences in light of a wider analysis of the area including various natural and cultural processes. He is thus able to explain the contrasting data and provide new insight into settlement patterns and economy at the start of the Neolithic.

Dag Erik Færø Olsen reviews the rock shelters in the mountain regions of Hardangervidda and Nordfjella. The previous interpretation of these settlement sites as primarily from the Late Neolithic and onwards is discussed based on a reclassification of archaeological material. The results show that rock shelters have been used from at least the Middle Mesolithic and in some cases with an intensification and stronger continuity after 2350 BC.

Gaute Reitan discusses the chronological division of the Mesolithic based on new data from excavations the last 20 years. Reitan presents a revised chronology for the Mesolithic in Southeast Norway dividing each of the three main phases into two sub-phases, adding two new phases to Egil Mikkelsen's original from 1975.

Acknowledgements

On the behalf of the organizing committee, we would like to thank all participants of *Steinalderkonferansen i Bergen 2017* for sharing their knowledge and for the discussions that followed at the conference. We also want to express our gratitude to the conference key note speakers, Prof. Kjel Knutsson (Dep. of Archaeology and Ancient History, Uppsala University), Assoc. Prof. Per Persson (Dep. of Archaeology, Museum of Cultural History, University of Oslo) and Prof. Charlotte Damm (Dep. of Archaeology, History, Religious Studies and Theology, The Arctic University of Norway) for introducing three of the conference sessions. This gratitude is also extended to five session leaders, Assoc. Prof. Arne Johan Nærøy (Museum of Archaeology, University of Stavanger), Prof. Marianne Skandfer (The Arctic University Museum of Norway), Assoc. Prof. Birgitte Skar (Dep. of Archaeology and Cultural History, NTNU University Museum), Prof. Hans Peter Blankholm (Dep. of Archaeology, History, Religious Studies and Theology, The Arctic University of Norway) and Prof. Almut Schülke (Dep. of Archaeology, Museum of Cultural History, University of Oslo).

During the three-day conference the committee received assistance from voluntary students from The University of Bergen and they provided valuable help during the conference.

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The editor of this anthology would further like to express gratitude to all the anonymous peer reviewers whose valuable comments and insights has made this publication possible.

Last, but not least, thank you to the authors of this anthology for the patience and work on the papers that make out this volume.

Dag Erik Færø Olsen and Tina Jensen Granados – Oslo 2021

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Kenneth Webb Berg Vollan

Dwellings as population proxies? Identifying reuse of coastal Stone Age housepits in Arctic Norway by means of Bayesian modelling of radiocarbon dates

Almost for a century, the archaeological record of the coastal Stone Age housepit sites in Arctic Norway has been at the centre of attention in many archaeological studies of this region. Although housepit reuse is occasionally recognised in particular cases, the theme does not get the proper attention it deserves. Since the early 1990s, an increasing number of radiocarbon samples have been dated, and the most recent excavations provide ^{14}C-dates from single dwelling structures in quantities not formerly seen. Frequently, the radiocarbon determinations from one housepit prove to be widely spread in time, and hint towards the possibility of reuse. Here I contribute to the subject by outlining a formal method for analysing radiocarbon dates to detect episodes of housepit reuse, and by presenting the first estimation of the magnitude of the phenomena on a larger scale. Radiocarbon dates from three large-scale excavation projects, conducted between 1991 and 2010, are modelled following the Bayesian approach, and the chronological relationship between the dates is evaluated by statistical testing. The analysis reveals that housepit reuse is far more common than hitherto acknowledged, consequently each housepit can represent multiple household generations.

Introduction

For decades, the Stone Age housepits on the coast of Arctic Norway have been of major interest for archaeologists working in the region, perhaps because they offer a physically perceptible fixed point for relating the archaeological record to past households and societies. In the few attempts to estimate prehistoric population sizes, both on single sites and in larger regions, the housepits have functioned as the key proxy (Andreassen 1985, p. 235–250, E. Helskog 1983, p. 150, K. Helskog 1984, p. 65–66, Schanche 1994, p. 175–177, Simonsen 1996, p. 118–122). The line of arguments behind the traditional estimation method consists of several stages. First, estimates of the number of housepits (supposedly) contemporaneous or used within the same chronological phase were made. Often, shoreline dating forms the basis for suggesting relative chronological order and relations between housepits. It follows the principle that housepits higher above present sea level are older than housepits on lower levels, and those on the same height levels are approximately of the same age or relatively close in time (e.g. Helskog 1984, Simonsen 1996). Secondly, one proposes how many households the contemporary housepits were inhabited by, and estimate the average number of individuals per household. Estimation of household size is often based on a combination of ethnographic information and housepit floor size. Finally, the population size estimate is the product of multiplying the number of individuals in a household with the number of households represented by the housepits. The same reasoning also lies behind estimations of population sizes in other regions with different culture-historical contexts (e.g. Müller *et al.* 2016, p. 134, 164, Birch-Chapman *et al.* 2017, p. 5; see also Hassan 1981, p. 72–75, Schacht 1981, p. 125–126, and references therein).

A major concern with this method is that it virtually disregards the possibility of housepit *reuse*. This is the main topic in this paper. I attempt to utilise radiocarbon dates from three large-scale excavation projects (Fig. 1) to detect housepit reuse, and to estimate the magnitude of the phenomenon. Does housepit reuse occur frequently or only in exceptional cases? The data source is restricted to the radiocarbon samples and the information about their archaeological contexts. An important aspect of this article is to develop a formal method for utilising that specific data to detect reuse; therefore, emphasis is put on methodological issues. Consequently, at this stage there will be little room for identifying spatio-temporal patterns and discussing possible explanations of the results in a cultural-historical context. The analysis aims at giving a minimum estimation, more than an exhaustive picture of housepit reuse. Nonetheless, the analysis will offer a more solid foundation for assessing whether reuse has an impact on our understanding of Stone Age housepits as a demographic proxy.

The housepits are often well visible on the ground surface and occur in relatively high numbers along the coast. The term *housepit* is applied to designate the archaeological remains of houses where the floor is situated below the ground level, often referred to as semi-subterranean houses or pit houses. The floor depth varies from a few centimetres to over half a meter, and the size from below eight m^2 to around 50 m^2. Often there are wall mounds surrounding the floors; the wall height can vary from a few centimetres up to half a meter (Engelstad 1988). On the coastal sites, the housepits tend to cluster and often forming rows following shoreline ridges or terraces. A typical site contain from five to twenty-five housepits. They have been radiocarbon dated back to around 7000 BC (Skandfer *et al.* 2010, p. 82–115), and as late as the early Iron Age (Skandfer 2012, p. 158–162). However, the majority of housepits are dated between 5000 BC and BC/AD.

The traditional application of housepits as a demographic proxy reflects a view on housepits as closed chronological units; they represent *one* dwelling structure inhabited by *one* household generation. However, recent resource management excavations, and especially their radiocarbon dating programs, provide chronological information making it reasonable to systematically assess the archaeological record related to Stone Age housepits (see also Hood and Helama 2010). Since the early 1990s, an increasing amount of samples from housepits has been ^{14}C-dated. Frequently, the ^{14}C-dates prove to be widely spread in time, indicating that many of the housepits have a far more complex use-history than captured by the traditional housepit-proxy approach.

To deal with the archaeological complexity that often follows from situations where multiple, chronologically spread occupations unfold within the same area, I regard it as useful to replace the term *housepit* with *dwelling plot*. Dwelling plot is the area upon where a dwelling structure is erected – the dwelling footprint (Fretheim 2017). The term helps to differentiate between

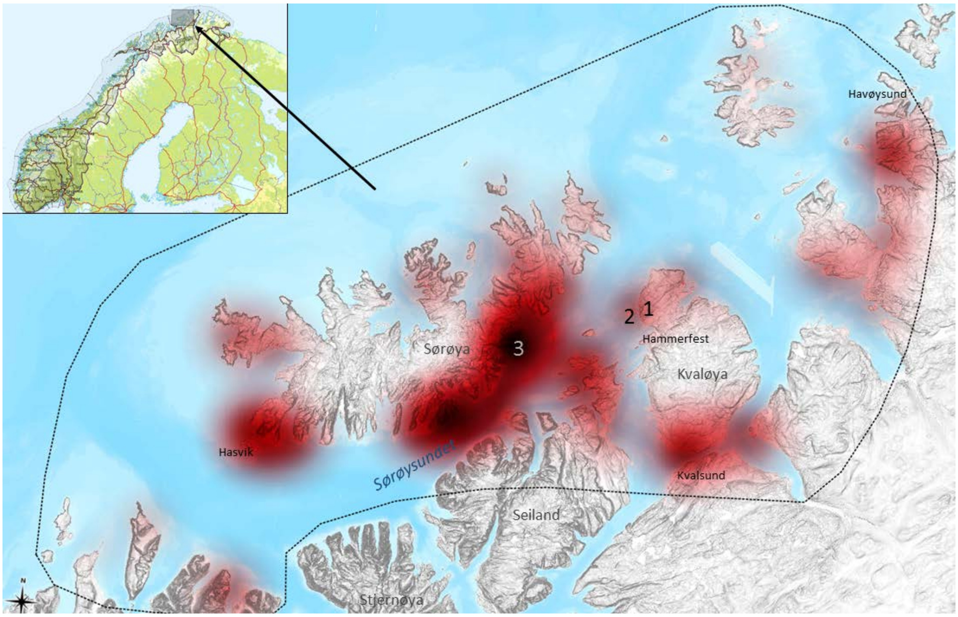

***Figure 1**: Map of the Sørøysund region and adjacent areas, western Finnmark. Within the map area there are more than 1400 recorded Stone Age housepits, the light to dark red colouring on the map indicates density of recorded housepits from low to high. The dotted line indicates the boundary for the density analysis. The numbers mark the locations of the excavation projects providing data for the reuse analysis; 1=Fjellvika/Skjærvika; 2=Melkøya; 3=Slettnes. They are situated in areas with a varying density of housepits. Scale 1:400 000. Background map © Kartverket.*

the dwelling structure and the area it is built upon, the plot. Moreover, this makes it easier to envision that multiple dwelling structures could have occupied the same plot at chronologically separate periods, and to acknowledge the concept of reuse. Besides, the dwelling plot term embraces all types of dwellings, including tents and lean-tos built on the ground surface, and not only the semi-subterranean houses normally associated with housepits. Here, dwelling plot *reuse* refers to situations when a new dwelling structure is erected on the same plot where an earlier dwelling once stood, and where the interval between the two episodes of dwelling habitation indicates that they cannot represent the same household generation.

Sites and data selection

From the three selected excavation projects, the compilation of analysis data is restricted to seven coastal sites in western Finnmark (see Fig.1). These are (1) Fjellvika and Skjærvika on Kvaløya (Gil *et al*. 2005, Henriksen and Valen 2009, 2013), (2) Sundfjæra and Normannsvika on Melkøya (Hesjedal 2009), and (3) three sites from Slettnes on Sørøya, Slettnes III, IV, and V (Damm *et al*. 1993, Hesjedal *et al*. 1993, 1996). In the excavation reports, all the sites except Slettnes III are sectioned into smaller units, but here the subdivisions are merged. As such, each larger site includes a variety of structure types (e.g. house remains, activity areas, graves and slab-line pits) distributed at different levels above the present shoreline. Chronologically, the structures range from Early Stone Age and well into the Iron Age, some even to modern times (Fig. 2).

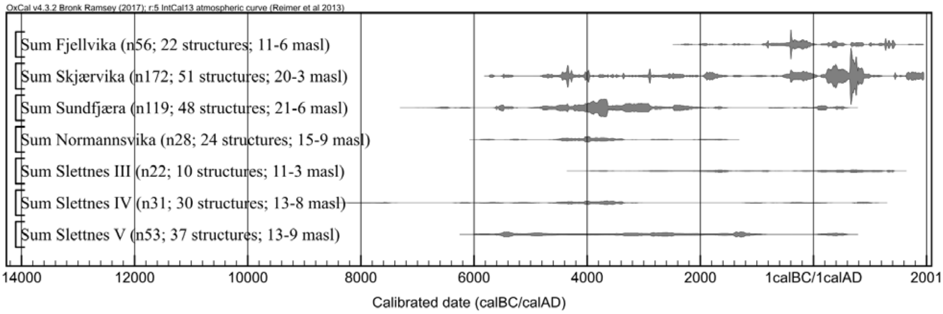

***Figure 2**: Summed probability distribution (SPD) of all ^{14}C-dates from each site, indicating the span of human activity. Note that four ^{14}C-dates from Normannsvika are excluded from the SPD, because they are not related to site occupation. Behind the site names is the number of ^{14}C-dates, the number of excavated structures on the site, and the range in meters above sea level of these structures.*

The reuse analysis concerns only the Stone Age dwelling plots (supplemental Table 1). In this paper, to be defined as *Stone Age*, there must be at least one ^{14}C-date indicating that the dwelling plot was established before BC/AD. Once it is determined that a plot was established in the Stone Age, all its ^{14}C-dates relating to dwelling habitation are included in the reuse analysis, even those younger than BC/AD. Dwelling plots only containing ^{14}C-dates younger than BC/AD are labelled *too young* and excluded from the analysis.

Figure 3 displays the number of excavated dwelling plots on each site and the years of excavation. The third column give the number of dwelling plots labelled too young and those that lack ^{14}C-dates associated with a dwelling habitation. Stone Age dwelling plots containing only one ^{14}C-date associated with a dwelling habitation are shown in the fourth column. For these dwelling plots, the ^{14}C-dates cannot display potential reuse, thus they are excluded from the analysis. The number of dwelling plots included in the reuse analysis is displayed in the second last column, i.e. those with two or more ^{14}C-dates representing dwelling habitation, and the last column shows how many ^{14}C-dates that sums up to be. Because Figure 3 is based on a re-evaluation of the relationships between dwelling plots and radiocarbon samples, the number of ^{14}C-dates associated with each dwelling plot might differ slightly from how it is presented in the excavation reports.

Site name	Excavation year	Excavated	Too young, or none ^{14}C-dates	With one ^{14}C-date	Two or more ^{14}C-dates	^{14}C-dates in reuse analysis
Fjellvika	2009–10	9	5	0	4	20
Skjærvika	2009–10	26	11	4	11	40
Sundfjæra	2001–02	19	0	4	15	56
Normannsvika	2001–02	13	2	7	4	9
Slettnes III	1991–92	9	2	1	6	15
Slettnes IV	1991–92	13	6	5	2	4
Slettnes V	1966, 1991–92	20	8	3	9	25
Total		109	34	24	51	169

***Figure 3**: Table of data from the sites included in the reuse analysis. In the two last columns, the table presents the number of dwelling plots and ^{14}C-dates from each site that are included into the reuse analysis. It also shows the number of excavated dwelling plots and how many that are unsuitable for the analysis. For more detailed description of table, see text.*

A total of 282 dated samples were obtained during excavation of housepit structures (supplemental Table 2), of which 169 are *strongly associated with dwelling habitation* (see below) in the 51 dwelling plots accepted into the reuse analysis. There are 165 ^{14}C-determinations on charcoal, three on crust from ceramics, and one on a sample containing marine shells (*Mytilus edulis* and *Patellidae*). The charcoal in 123 of the dated samples is identified as deriving from short-lived species (mainly *Betula*, *Sorbus*, *Prunus*, *Salix*, *Populus*). One sample contained larch (*Larix*) that did not grow naturally in the study area and must originate from driftwood. For the remaining 41 radiocarbon determinations on charcoal, the sample taxa are unidentified, and all except one are from the Slettnes sites. The conventional radiocarbon dating method was used on 63 samples, while 106 were dated by accelerator mass spectrometry (AMS), which gives a more precise age determination.

Selection criteria: radiocarbon samples representing dwelling habitations

It is important to remember that radiocarbon dates essentially date the sample, not the sample context. Therefore, in every case one must assess the sample material and the relations between samples and their contexts (Waterbolk 1971, p. 15–16, Bayliss 2015, p. 688–690). When exploring dwelling plot reuse by means of ^{14}C-dates, evaluating the associations between contexts and past events is paramount. As a guideline for this study, radiocarbon samples from contexts interpreted as floor layers, and features situated in these floor layers, are presumed to represent dwelling habitation, unless the stratigraphy or context indicate otherwise. Floor areas are commonly defined by being semi-subterranean, or a cleared area, often surrounded by wall mounds or a line of stones (e.g. Engelstad 1988, Skandfer 2012, Fretheim 2017). The floor layers often contain lithic debris, charcoal, ash and organic matter. Sometimes this is more blended into the natural beach gravel than accumulated in solid cultural layers. Samples procured from hearths integrated into the floor layers are considered particularly reliable when dating a dwelling habitation.

Samples from contexts probably deposited in the floor area of a dwelling after its abandonment, and from pits cutting floor layers, are considered weakly related, or not related at all to dwelling habitation. In the case of survey test pitting the conditions are poorer, compared to excavation situations, for interpreting the contexts the samples are obtained from, so there might be a greater risk for blending sample material from chronologically different deposits. Given this, the association between test pit samples and dwelling habitations are here categorized as weak, and thus excluded from the reuse analysis.

Charcoal in wall areas can have several possible explanations. In the excavation reports, some of the samples obtained from wall areas or outside the dwellings are interpreted as refuse dumps from dwelling hearths. Potentially, charcoal in wall areas can derive from wooden structure elements. If the dwelling plot was reused, the charcoal originally could have been deposited in the floor area, but later re-deposited in the wall when the plot was prepared for a new superstructure. Alternatively, charcoal mixed into wall material could have been deposited during an earlier period of open-air activities, when there was no functioning dwelling structure on the plot (Fretheim 2017, p. 76–89). In addition, the wall could have been built upon an older cultural layer, or, as suggested in the excavation report from Slettnes (Hesjedal *et al.* 1993, p. 113, 163), the wall material might have been taken from neighbouring housepits or other, earlier activity areas. Since the origin of wall-samples is difficult to interpret, all the ^{14}C-dates from the wall areas are excluded from this reuse analysis. I do not consider samples from features and cultural layers outside the dwelling plots as directly related to a dwelling habitation. This also applies for sampled features or deposits associated with a dwelling by the excavators, which is often the case for abutting middens, heaps of fire-cracked rocks and nearby open-air hearths and cooking pits.

Radiocarbon dates as data: critical issues

There are critical issues concerning ^{14}C-dates as a source. Depending on the archaeological situation, some are more relevant than others (see Bayliss 2015). Along with the effect of the wiggles in the calibration curve, which is described below, sample materials and sampling routines are the factors with the highest potential for obscuring the reuse analysis. Marine material and the reservoir effect is one of the critical issues concerning the sample material. There is one sample representing dwelling habitation on Slettnes IV containing marine shells. For reservoir correction I use a ΔR value of 13 ± 40, which is the weighted average of two correction estimates on whale bones (Mangerud *et al.* 2006) and one on *Mytilus edulis* (Mangerud 1972). The correction samples are from two different locations, both approximately 40 km away from Slettnes (supplemental Figure 1). Due to high $\delta^{13}C$-values in the three crust samples taken from ceramics found at Slettnes V, indicating a considerable content of marine mammal lipids, corrections were made by the radiocarbon laboratory following a standard procedure of reducing the radiocarbon age by 440 years (Oppvang 2009, p. 85).

A different issue regards the old wood effect, including driftwood. Only one sample consists of charcoal identified as a long-lived species, driftwood of larch. However, since the sample dates to the same habitation episode as a charcoal sample of birch from the same dwelling plot, it is accepted into the reuse analysis. If the larch sample alone represented a habitation episode, it would have been excluded from the reuse analysis because it potentially has a much higher ^{14}C-age than the deposits it is associated with. Regarding the Slettnes sites, where all the charcoal samples lack wood species identification, it is difficult to evaluate if the old-wood effect has an impact on the reuse analysis of the Slettnes sites, or to what degree.

Another issue concerning particularly the Slettnes excavations is charcoal sampling routine. The formerly used conventional radiocarbon dating method required a large amount of material for measuring the ^{14}C-age (Bayliss 2009, p. 125). At the Slettnes excavations in 1991 and 1992, for the samples to be large enough for conventional radiocarbon dating, charcoal fragments with a relatively wide horizontal distribution occasionally were gathered into the same bag. This increases the risk of blending charcoal from chronologically separate depositions into the same sample, but it is difficult to estimate the actual impact this has on the analysis results. At the time of the Melkøya excavations in the early 2000s, both sampling routines and stratigraphic documentation had improved significantly. Smaller amounts of charcoal were required for conventional radiocarbon age measurements, and dating by AMS had become much cheaper and thus more available as a dating method (Bronk Ramsey *et al.* 2004, Bayliss 2009, p. 125–126). At Melkøya, there was an explicit strategy to obtain samples from stratigraphic profiles and with a limited spatial distribution, and to secure detailed documentation of their contexts (Hesjedal *et al.* 2009, p. XI). This was followed up in the later projects at Skjærvika and Fjellvika. It is important to note that even with smaller samples from distinct contexts, there is still a risk of mixing charcoal related to chronologically different activities (Ashmore 1999). Nonetheless, I consider the risk generally lower compared to larger samples containing more widely distributed material.

Bayesian modelling of radiocarbon dates

Bayesian modelling (Buck *et al.* 1996) provides a formal statistical framework for combining radiocarbon dates with information about stratigraphic relationships between the dated samples. The basic principle behind the modelling algorithms in calibration software, such as OxCal (Bronk Ramsey 2009a) and BCal (Buck *et al.* 1999), are based on Bayes theorem, which is probabilistic and can be expressed as *standardised likelihoods x prior beliefs = posterior beliefs* (Buck *et al.* 1996, p. 19–21, Bayliss 2009, p. 127–129, Hamilton and Krus 2018, p. 189–190). Transferred to an archaeological situation, the calibrated radiocarbon dates form the standardized likelihoods, and prior beliefs are the existing knowledge about the archaeological contexts of the dates, which indicates their relative chronological order. The archaeological information is used to constrain the calibrated radiocarbon dates, and the new, constrained age estimates are the posterior beliefs, or the modelled dates (Bronk Ramsey 2009a, Bayliss 2011, p. 19–35).

How a model is structured should reflect the archaeological questions to which it is meant to respond. In a site-specific context, the relative chronological order of stratigraphy, features, and deposits often form the basis of the model structure (e.g. Macsween *et al*. 2015, Richards *et al*. 2016, Card *et al*. 2018). Following this approach, the ^{14}C-dates from the seven study sites are arranged in stratigraphic site-models. In many ways, the model structures resemble a Harris matrix. If a group of contexts can be sorted in a relative chronological order, the samples can be modelled in a sequence, according to that order (Bronk Ramsey 1995, p. 463). Samples from relatively older deposits should date earlier than samples from younger deposits. If two samples are procured from the same context and strongly associated in time, e.g. charcoal from the same burning event, then the radiocarbon ages should calibrate approximately to the same dates.

By constraining the ^{14}C-dates in models, the chronological precision level is potentially enhanced, which improves the ability to estimate the timing of archaeological events, the tempo of change and duration of phases (Whittle *et al.* 2011). Important to note, the method also provides a framework for formal analysis, as opposed to informal eye-balling of calibration results, which has generally been the case in Norwegian Stone Age research (see however E. Helskog 1983, K. Helskog and Schweder 1989). When narratives of the past are based on visual inspection of calibration results alone, it has been shown that archaeologists generally assume archaeological events or phases to start earlier, last longer and end later than what is plausible (Bayliss *et al.* 2007, p. 8–9, 25). Concerning the issue in this paper, Bayesian modelling should be a beneficial approach when using the radiocarbon dates to define dwelling habitation episodes and detect reuse.

I use the calibration program OxCal v4.3 (Bronk Ramsey 1995, 2001, 2009a) to model the data analysed in this article. For all dates, the IntCal13 (Reimer *et al.* 2013) calibration curve is applied, except for the sample of marine shells from Slettnes, which is calibrated using the Marine13 curve (Reimer *et al.* 2013). Modelled dates and statistical estimations based on these dates are given in italics, and have been rounded outwards to the nearest five years and refer to the calendar BC/AD scale.

The models can be diagnosed to see if there is good agreement between the radiocarbon dates and the model. The most important is the model agreement index, A_{model} (Bronk Ramsey 2009a, p. 356–357). For each date there is also calculated an individual agreement index A, which measures the agreement between the posterior distribution (the modelled date) and the (unmodelled) calibrated radiocarbon date. These values are used to calculate an overall agreement index, $A_{overall}$, for the model as a whole (Bronk Ramsey 1995, p. 429). For all the agreement indices, the value should stay above 60%. If the A_{model} and $A_{overall}$ values are below 60%, there could be a problem with the model. Lower values for the individual dates indicate that it might be an outlier of some kind (Bronk Ramsey 2009b). Re-deposition and post-depositional mixing of deposits (Schiffer 1987, Bailey 2007, p. 204–207) might cause a collapse of the law of superimposition (Brantingham *et al.* 2007, p. 517). When residues from one event are blended into a context related to a chronologically different event, it can affect how well the ^{14}C-dates fits the relative chronological order of a stratigraphic sequence.

The site-models

The reuse analysis presented here is based on carefully selected ^{14}C-dates, yet all the radiocarbon dates are included in the Bayesian models for each site. This is to ensure that the models are as robust as possible, and to prevent the selected data from being disentangled from its larger context. The models do not only provide an overall impression of the sites' occupation histories; they also function as a powerful tool when evaluating the radiocarbon dates in relation to each other and to the site deposits: the integrity of contexts and stratigraphic layers. Is the relative order of layers chronologically sound? What is the age difference between discrete layers in a stratigraphic sequence? Do the deposits represent single archaeological events or are they an aggregation of material from chronologically different episodes?

Model building is a dynamic process that often involves a repetitive procedure of modelling-evaluation-re-modelling (Bayliss 2007, p. 4–5). For each model, there are site-specific challenges that need to be handled, and the procedures can be repeated several times before the final model is reached. There will always be an element of interpretation when structuring models according to stratigraphic information, and sometimes hypothesis testing is exactly the point of modelling. Here, however, I aim at defining and detecting occasions of dwelling plot reuse on a rather large dataset. Therefore I have had an explicit strategy of keeping the models as simple as possible (see Bayliss and Bronk Ramsey 2004), and to accept limitations in the available archaeological information. If the stratigraphic relations between samples appear unclear in the report and field documentation, no constraints are added based on ambiguous interpretations of how the relations could have been.

In each of the site-models for Fjellvika, Skjærvika and Sundfjæra (supplemental Figure 2–4), all radiocarbon dates are grouped within a single phase. Each phase represents the site-occupation, irrespective of duration. The ^{14}C-dates from Normannsvika are structured into three sequential phases (supplemental Figure 5). The first phase contains dates from layers covered by transgression sediments, the second contains the dates related to site occupation after the Tapes-transgression maximum, which is when the dwelling plots were used, and the third phase contains charcoal samples from the turf covering the site. The ^{14}C-dates from Slettnes are structured into three separate, chronologically overlapping phases, which respectively represent the occupation of the sites III, IV and V (supplemental Figure 6). In all models, within the phases representing larger site occupations, radiocarbon dates from single archaeological features are arranged into distinct groups (e.g. dwelling plot). If there is information about the relative chronological order of samples belonging to the same structure, they can be constrained. For example, by sequencing samples from the top and bottom layers in a hearth, or samples from hearths stacked in different floor layers.

All the site-models in this study have acceptable agreements; the A_{model} values from the models of Fjellvika, Skjærvika, Sundfjæra, Normannsvika and Slettnes are respectively 97%, 80%, 94%, 90%, and 97%. In addition, the $A_{overall}$ values are above 60%. Five of the dwelling plots included in the reuse analysis, two from Skjærvika and three from Sundfjæra, contain ^{14}C-dates returning poor agreement when modelled in a sequence according to their stratigraphic order. For three of the plots, the reuse analysis demonstrates that the date estimates of the misfit samples overlap other date estimates representing dwelling habitation on the same plot. This indicates that the stratigraphic sequences are disturbed, possibly due to post-depositional processes. Since they have no impact on the final analysis results, the misfit dates from these three plots are kept in the models.

The fourth plot (one from Skjærvika) contains six floor samples, which are modelled in a sequence of four stratigraphic levels. Also, here post-depositional mixing of deposits might explain why the radiocarbon age of two samples are inconsistent with the relative chronological order of the stratigraphic layers. However, both are kept in the model and each represents their own habitation episode. Consequently, the reuse analysis counts four episodes of dwelling habitation on the plot. If both samples were removed, the analysis would still conclude that the plot was reused, but only once. A third floor sample from this plot, which is approximately thousand years older than the other floor samples, is removed from the floor sequence because its large offset prevents the model analysis to run appropriately. It is also excluded from the reuse analysis.

The low agreement in the fifth dwelling plot (from Sundfjæra) is caused by two samples from a hearth; the sample from the top layer dates earlier than the sample from the bottom layer. The latter sample dates to the same time as a third sample representing dwelling habitation in the plot. Possibly, the relative stratigraphic order is disturbed due to mixing of the hearth deposits, or one of the hearth dates could be an outlier. Both samples from the hearth are kept in the model and the reuse analysis. If it were possible to demonstrate that the sample from the top of the hearth provided an older date than expected because of contamination or other incidents affecting the reliability of the date, it would have been removed. Then the reuse analysis would have counted one habitation episode on the dwelling plot.

The reuse analysis

The reuse analysis is based on two operations. First, it is statistically determined how many dwelling habitation episodes the dated radiocarbon samples represent for each plot. The chronological relationships between the ^{14}C-dates are evaluated by X^2-testing (Ward and Wilson 1978), which defines whether two or more ^{14}C-dates are statistically consistent or not (Bronk Ramsey 1995, p. 429). If consistent, the ^{14}C-dates possibly relate to events occurring contemporaneously or relatively close in time. If the test fails, the dates probably relate to events from chronologically different habitation episodes (see also Steele 2010, p. 2020–2021, Wicks *et al.* 2016, p. 11). When two or more ^{14}C-dates from the same dwelling plot are from chronologically different episodes, i.e. not statistically consistent, it is taken as a signal of reuse. Important to note, the X^2-test works on the uncalibrated radiocarbon ages.

The second operation of the analysis is therefore to apply the site-models for assessing the results from the X^2-tests. This is done by combining the posterior distributions (the modelled dates) of the samples with statistically consistent ^{14}C-ages, i.e. the samples that probably represent the same habitation episode. The combine function in OxCal can be used on dates that are relatively close in time, and expected to refer to the same event (such as a dwelling habitation episode). If the overall agreement of the combination (A_{comb}) is above 60%, the assumption that the ^{14}C-dates represent one habitation episode is strengthened. If the A_{comb} shows poor agreement, it might indicate that the ^{14}C-dates represent a long-term regular use of the dwelling plot, or that it was reused within a relatively short interval.

If two ^{14}C-dates from the same plot are chronologically adjacent or marginally overlapping, but still prove to be statistically inconsistent with each other, it could possibly be a result of long-term regular use. Nonetheless, in a situation like that, the X^2-analysis will find two habitation episodes. Again, the modelled dates can be used for evaluating the X^2-test results, both by combining and by estimating the interval between the episodes. I have done this on all dwelling plots where the X^2-test indicates two habitation episodes. In archaeological studies, the average age-at-death of a human normally is well below 60 years, and only a few individuals lived longer (see Chamberlain 2006, p. 81–92 and references therein). Therefore, if the minimum range of the estimated interval between the dwelling habitation episodes is more than 60 years, this is taken as a sign of reuse.

The shape of the calibration curve is a known concern when it comes to radiocarbon dating (e.g. Ames 2012, p. 176–178, Williams 2012, p. 581–583). When ^{14}C-dates hit a plateau in the calibration curve, the probability distribution can exhibit a wide chronological range and give a false impression of longevity. This could affect the reuse analysis directly. If two or more dates from the same dwelling plot, but from different contexts deposited during chronologically separate habitation episodes, hit the same plateau, there is good chance that the X^2-test will find the ^{14}C-dates to be statistically consistent. Potentially, the plateau effect can disguise that there were considerable time-gaps between the dated events, and that the dwelling plot had multiple habitation episodes. The larger the standard error is for the ^{14}C-measurements, the larger is the risk that reuse episodes are blurred out. By using Bayesian modelling it is possible to partly deal with such issues.

Analysis results: Reuse of Stone Age dwelling plots

As Figure 3 displays, 51 dwelling plots are suitable for the reuse analysis, and from these there are 169 ^{14}C-dates associated with dwelling habitation. One hundred of these dates are from hearth contexts, and 67 are from other features mounted in floor layers or from the floor layers themselves. Additionally, two of the plots in Fjellvika have one sample each that offers a *terminus post quem* (tpq) for their third and last dwelling habitation episodes. In dwelling plot 23, the tpq-date is taken from the turf layer found under one of the stones in a tent-ring, and above the floor-layer of an earlier dwelling structure. The tpq-date in dwelling plot 24 is from a similar context, but the upper dwelling is a post AD 1650 structure with turf walls.

Running the X^2-test on the ^{14}C-determinations from their respective dwelling plots returns signals of reuse in 39 plots (Fig. 4, also see supplemental Figures 7–11), whereof 18 have three or more habitation episodes. For 20 dwelling plots, the X^2-test finds that the ^{14}C-dates represent two habitation episodes. The posterior distributions from the site-models are applied to evaluate the chronological relationship between episode one and two in each of these plots (Supplemental Table 3). For 14 of these plots, the estimated interval between habitation episode one and two exceeds 100 years (*95.4% probability*). Thus, the modelled dates substantiate that these plots probably have been reused. For three dwelling plots (from Slettnes), the modelled dates of episode one and two, as defined by the X^2-test, are slightly overlapping. For each plot, the estimated interval between the modelled dates are *0–690 years, 0–760 years*, and *0–785 years* (*95.4% probability*). Although the ^{14}C-dates indeed could represent two habitation episodes separated by an interval potentially spanning hundreds of years, this also opens up the possibility that the ^{14}C-dates represent only one episode of habitation. Since the ^{14}C-dates can be interpreted in both directions, the dwelling plots can be catorized as ambiguous (Fig. 4).

There is a similar situation for the remaining four plots (two from Sundfjæra, one from Normannsvika, and one from Slettnes), where the X^2-test indicates two habitation episodes. Here the modelled dates from episodes one and two do not overlap, but the shortest interval between the episodes is estimated from 35 to 55 years (*95.4% probability*). Given this, the interval estimations make it possible to suggest that the ^{14}C-dates represent long-term, regular use of the plots. The plots have therefore been re-categorised as ambiguous. However, the upper range of the interval estimations lies between 360 and 635 years (*95.4% probability*). Hence, dwelling plot reuse is still a plausible interpretation. Note that for all the 21 dwelling plots where the X^2-test indicates two habitation episodes, the intervals in the models are estimated to exceed a minimum of 95 years at *68.2% probability*.

In 12 dwelling plots, the X^2-test indicates that the ^{14}C-dates represent only one dwelling habitation episode. When combining the modelled dates from each of these plots, all return an A_{comb} value above the threshold of statistical consistency and substantiates the probability that the ^{14}C-dates represent one episode of dwelling habitation. However, for two plots individual modelled dates are in poor agreement with the overall combine result, which indicate that the ^{14}C-dates might represent two habitation episodes, or a phase of long-term regular use. Hence, the two plots (both from Sundfjæra) are added to the ambiguous-category. As displayed in the three last columns in Figure 4, in 32 dwelling plots both the X^2-test and the Bayesian models evidently indicate reuse. Nine dwelling plots fall into the ambiguous-category, which holds the plots for which it is problematic to distinguish reuse from a long-term dwelling habitation. Lastly, in ten plots the ^{14}C-dates are consistent with only one habitation episode.

Sites	X^2-test		Adjusted according to models		
	Reused	Not reused	Reuse confirmed	Ambiguous	No-reuse confirmed
Fjellvika	4	0	4	0	0
Skjærvika	9	2	9	0	2
Sundfjæra	10	5	8	4	3
Normannsvika	2	2	1	1	2
Slettnes	14	3	10	4	3
Total	39	12	32	9	10
			(63%)	(18%)	(20%)

***Figure 4**: Table of dwelling plot reuse. The first two columns display the reuslts of the X^2-testing on the uncalibrated radiocarbon ages. The last three columns show the final result of the reuse analysis, after the modelled dates is analysed to evalute the X^2-tests. See text for further description.*

The best data quality, in terms of number of dated samples per plot and precision of radiocarbon age measurements, is found at the Fjellvika and Skjærvika sites. It is also here that the highest proportion of reuse is identified. Concerning the Melkøya project, the data quality for Normannsvika is notably poorer than for Sundfjæra. From Normannsvika there are fewer ^{14}C-dates and dwelling plots suitable for the reuse analysis, and almost none of the charcoal samples are related stratigraphically. This might explain why the magnitude of dwelling plot reuse is considerably lower in Normannsvika compared to the other sites. However, it should be noted that on a general level there probably are between-site differences, which cannot be explained solely by the data situation. The analysis results of the Slettnes sites, belonging to the third and oldest developmental project, fits well with the general picture. This might imply that sample material and changes in sampling routine is not significantly affecting the results. The reuse trend is relatively consistent on all sites, despite the varied data quality, and the chronological and topographical differences. This offers strength to the analysis results.

Discussion

Important to note, this analysis probably gives a *minimum* estimation of the frequency of dwelling plot reuse. Radiocarbon samples and information about their stratigraphic and contextual relationships are the only data source applied in the reuse analysis. In addition, the analysis is based on a careful selection of samples, only including those reasoned to be strongly associated with dwelling habitation. Moreover, only 37 of the 51 analysed dwelling plots are fully excavated. By dating more samples or by adding information from other types of data, the analysis can be further developed. For instance, if there are stacked floor layers and/or dwelling features (e.g. walls, hearths), if chronologically distinct artefact types and technologies from different periods are found in the same dwelling plot, or if the artefact material does not match the ^{14}C-dates, this could be indications of dwelling plot reuse. Nevertheless, the analysis presented above demonstrates that reuse of Stone Age dwelling plots is a frequently occurring phenomenon.

Of the 31 dwelling plots with three or more dates, the analysis identifies 18 plots with three or more habitation episodes. Thus, it is not unusual for dwelling plots to have been reused multiple times. The available data does not allow for going much deeper into detecting trends about how many times or how intensively dwelling plots have been reused. Still, they indicate variation. Two dwelling plots respectively contain eight and nine ^{14}C-dates that represent dwelling habitation, the analysis detects six separate habitation episodes in each. On the other hand, for two of the dwelling plots containing four and five ^{14}C-dates, the X^2-test finds only one habitation episode. This illustrates that the amount of reuse should be expected to vary, and that it often is crucial to have a certain amount of ^{14}C-dates from different contexts to be able to outline an adequate use-history of a dwelling plot.

The length of the intervals between dwelling habitation episodes can vary from hundred years to over a millennia. This clearly has implications for the reliability of shoreline dating, which is based on the assumption that housing structures generally were placed close to the contemporary shoreline (Bjerck, *et al.* 2008, Fig. 5.3, Henriksen and Valen 2013, Fig. 5.2). Possibly, shoreline dating might indicate approximately when a dwelling plot first were established, but, if the dwelling plot were reused multiple times, the shoreline dating method does not necessarily provide valid date estimates for all dwelling habitation episodes. Thus, since the chronological distribution of habitation episodes related to a dwelling plot can be spread over large timespans, one should be cautious not to put too much emphasis on assumptions about the relative chronological order of dwelling features based on their height above sea level. Still, at a coarser level shoreline dating might be useful. When areas at different height-levels on a site are topographically divided, for example by a steep slope, it appears in most cases of the analysed sites that all habitation episodes related to dwelling plots at the higher level are earlier than those at the lower level. However, within each height-level area it becomes problematic to differentiate dwelling plots chronologically according to height above sea level.

In relation to this, stability of site attractiveness can be viewed as a parameter mediating/constraining dwelling plot reuse. Attractiveness is a term combining several factors, such as landing conditions for boats, social aspects (e.g. closeness to kin, or renowned hunters), resource availability (e.g. closeness to reliable fishing areas, fuel), and other environmental conditions (e.g. drainage, windiness). If the attractiveness of a site, or a certain area on a site, remains stable over long periods of time, it should be expected that this particular area are occupied by residential groups more often compared to areas less attractive or only temporarily attractive. This also implies the prediction, which should fit most archaeologists' intuitive assumption, that dwelling plot areas at height-levels where the shoreline has remained stable for centuries are probably reused more frequently than plots at height-levels with more rapidly regressing shorelines. Furthermore, due to accumulation of residential activities within the same area over time, reuse could possibly be more common on smaller sites (or areas), where there is room only for a limited number of dwelling plots, than on larger, equally attractive sites.

When it comes to the spatio-temporal distribution of dwelling plot reuse, further investigation of the results is necessary before formally demonstrating any potential prominent patterns. At this stage the results seems to suggest that reuse is a general trend occurring more or less regularly. However, within certain periods markedly fewer episodes of reuse are identified. In the period between c. 3400–3000 cal. BC there is only one reuse episode, and in the periods between c. 1800–1500 and 1000–500 cal. BC there are two, or possibly only one in each. Although the significance of these observations is uncertain, since the analysed data are from a restricted number of sites, it is worth noting that these periods roughly coincides with times when human activity in the larger region seems to have been relatively low. The two first period follows a marked drop in the summed probability distribution of radiocarbon dates from northern Norway (Jørgensen 2018, Fig. 5), suggested to reflect demographic downturns (Jørgensen 2018, Damm *et al.* 2019). This fits with an assumption that periods with a higher population density within a given area should result in more dwelling plot reuse than periods with lower population density.

The last period has not been associated with particular demographic fluctuations on a larger scale. Further investigation is needed in order to suggest whether the reuse pattern of the last two millenniums BC is an artefact of the data, or if it echoes demographic changes on a more local scale, or changes in land-use or mobility strategies. It seems reasonable to assume that populations practicing high residential mobility will produce more dwellings than more sedentary populations. However, one must also consider that sedentary people might have dwellings at special camps. Theoretically, several parameters can affect the spatio-temporal distribution and magnitude of dwelling plot reuse, and not necessarily in straightforward ways. Here I have touched upon a few, which seems particularly relevant for this study.

Dwelling plot reuse can have a significant impact on the integrity of the associated archaeological record, including the dwelling feature (see also Binford 1982). Only in a few exceptional cases are there possible to distinguish traces of multiple dwelling features on the same plot. Even when a dwelling plot has been reused several times, the archaeological documentation are normally conceptualised as a representation of only one dwelling feature. Generally, there is a floor area of certain size and shape (and depth when it comes to semi-subterranean dwellings) surrounded by a set of walls, and with some other accompanying elements (e.g. hearths). This begs the question, to which dwelling habitation episode(s) does the feature attributes (and artefacts, for that matter) relate? If floor size functions as a proxy for household size, it is important to explicitly state which habitation episode(s) the floor size are associated with – it could be the last, the first, or, perhaps all – and preferably why.

The results presented in this paper clearly illustrate that the relationship between number of dwelling plots and population size is a complex matter. One dwelling plot can represent multiple household generations belonging to chronologically different periods. Consequently, before the Stone Age dwelling plots are applied as a demographic proxy, the link between the dwelling plots at hand and the population they are expected to represent ought to be carefully evaluated, both methodologically and theoretically. Doing this potentially will provided more reasonable population size estimates. Here I have presented a formal method for utilizing the growing radiocarbon assemblage to outline the use-life of Stone Age dwelling plots, which can aid in estimating more precise population sizes. Nevertheless, further research on dwelling plot reuse, and on the impact that reuse in general can have on the archaeological record is needed.

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Supplemental Materials

For supplemental material accompanying this article, visit https://doi.org/10.18710/AQ1AQJ. Note that OxCal-codes for the site-models are also available.

Supplemental Figure 1: Reservoir correction of sample containing marine material.

Supplemental Figure 2: Bayesian site-model of radiocarbon dates from Fjellvika.

Supplemental Figure 3: Bayesian site-model of radiocarbon dates from Skjærvika.

Supplemental Figure 4: Bayesian site-model of radiocarbon dates from Sundfjæra.

Supplemental Figure 5: Bayesian site-model of radiocarbon dates from Normannsvika.

Supplemental Figure 6: Bayesian site-model of radiocarbon dates from Slettnes.

Supplemental Table 1: Dwelling features documented on the sites used in this article.

Supplemental Table 2: Radiocarbon dates included in the Bayesian models.

Supplemental Table 3: Results of X^2-tests.

Supplemental Table 4: Interval lengths between habitation episodes.

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