Peer Community In Archaeology

Taking the Reverend Bayes to the seaside: Improving Norwegian Mesolithic shoreline dating with advanced statistical approaches

Felix Riede *based on peer reviews by 2 anonymous reviewers*

Isak Roalkvam, Steinar Solheim (2024) Comparing summed probability distributions of shoreline and radiocarbon dates from the Mesolithic Skagerrak coast of Norway. SocArXiv, ver. 5, peer-reviewed and recommended by Peer Community in Archaeology.
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The paper entitled "Comparing summed probability distributions of shoreline and radiocarbon dates from the Mesolithic Skagerrak coast of Norway" by Isak Roalkvam and Steinar Solheim (2024) sheds new light on the degree to which shoreline dating may be used as a reliable chronological and palaeodemographic proxy in the Mesolthic of southern Norway.

Based on geologically motivated investigations of eustatic and isostatic sea-level changes, shoreline dating has long been used as a method to date archaeological sites in Scandinavia, not least in Norway (e.g., Bjerck 2008; Astrup 2018). Establishing reliable sea-level curves requires much effort and variations across regions may be substantial. While this topic has seen a great deal of attention in Norway specifically, many purely geological questions remain. In addition, dating archaeological sites by linking their elevation to previously established seal-level curves relies strongly on the foundational assumption that such sites were in fact shore-bound. Given the strong contrast between terrestrial and marine productivity in high-latitude regions such as Norway, this assumption per se is not unreasonable. It is very likely that the sea has played a decisive role in the lives of Stone Age peoples throughout (Persson et al. 2017), just as it has in later periods here. However, many confounding factors relating to both taphonomy and human behaviour are also likely to have loosened the shore/site relationship. Systematic variations driven by cultural norms about settlement location, mobility, as well as factors such as shelter construction, fuel use and a range of other possible factors could variously have impacted the validity or at least the precision of shoreline dating.

By developing a new methodology for handling and assessing a large number of shoreline dated sites, Roalkvam and Solheim use state-of-the-art Bayesian statistical methods to compare shoreline and radiocarbon dates as proxies for population activity. The probabilistic treatment of shoreline dates in this way is novel, and the divergences between the two data sets are interpreted by the authors in light of specific behavioural, cultural, and demographic changes. Many of the peaks and troughs observed in these time-series may be interpreted in light of long-observed cultural transitions while others may relate to population dynamics now also visible in palaeogenomic analyses (Günther et al. 2018; Manninen et al. 2021). Overall, this paper makes an innovative and fresh contribution to the use of shoreline dating in Norwegian archaeology, specifically by articulating it with recent developments in Open Science and data-driven approaches to archaeological questions (Marwick et al. 2017).

References:

Astrup, P. M. 2018. *Sea-Level Change in Mesolithic Southern Scandinavia: Long- and Short-Term Effects on Society and the Environment*. Aarhus: Aarhus University Press.

Bjerck, H. B. 2008. Norwegian Mesolithic Trends: A Review. In *Mesolithic Europe*, edited by Geoff Bailey and Penny Spikins, 60–106. Cambridge: Cambridge University Press.

Günther, T., Malmström, H., Svensson, E. M., Omrak, A., Sánchez-Quinto, F., Kılınç, G. M., Krzewińska, M. et al. 2018. Population Genomics of Mesolithic Scandinavia: Investigating Early Postglacial Migration Routes and High-Latitude Adaptation. *PLOS Biology* 16 (1): e2003703. https://doi.org/10.1371/journal.pbio.2003703

Manninen, M. A., Damlien, H., Kleppe, J. I., Knutsson, K., Murashkin, A., Niemi, A. R., Rosenvinge, C. S. and Persson, P. 2021. First Encounters in the North: Cultural Diversity and Gene Flow in Early Mesolithic Scandinavia. *Antiquity* 95 (380): 310–28. https://doi.org/10.15184/aqy.2020.252

Marwick, B., d'Alpoim Guedes, J. A., Barton, C. M., Bates, L. A., Baxter, M., Bevan, A., Bollwerk, E. A. et al. 2017. Open Science in Archaeology. *The SAA Archaeological Record* 17 (4): 8–14. https://doi.org/10.31235/osf.io/72n8g

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Roalkvam, I. and Solheim, S. (2024). Comparing summed probability distributions of shoreline and radiocarbon dates from the Mesolithic Skagerrak coast of Norway, SocArXiv, 2f8ph, ver. 5 peer-reviewed and recommended by Peer Community in Archaeology. https://doi.org/10.31235/osf.io/2f8ph

Reviews

Evaluation round #1

DOI or URL of the preprint: **https://osf.io/preprints/socarxiv/2f8ph/**
Version of the preprint: 2

Authors' reply, 01 January 2024

Dear Felix and reviewers,

We are grateful for the comments from the reviewers – both raised some very important points. While we believe in the general utility of shoreline dating, we recognize that it is far more uncertain and less explored

than more common archaeological dating methods. Understanding the accuracy, precision, the nature of the numerical results and the conceptual underpinnings of the method remains a challenge. We therefore aim to be as transparent about potential limitations as possible, and highlight the various ways in which the SSPD could be biased. The reviewers have helped greatly in this regard and made us aware of perspectives that we hadn't adequately considered. In combination, these have warranted even more caution when drawing any cultural-historical inferences.

- We have rewritten the possible influence of mobility patterns on the results to be more cautious, following Reviewer 1s suggestion that "Instead of saying that 'SSPD is heavily influenced by mobility', I would say that 'SSPD could be influenced by mobility'."

- As per Reviewer 1's suggestion, we carried out an analysis of the RSPD which accounts for taphonomy. As the analysis of the radiocarbon data was mainly done using ADMUR, we followed the workflow for accounting for taphonomy as outlined in the vignette that accompanies the package (Section 5 in: https://cran.r-project.org/web/packages/ADMUR/vignettes/guide.html). Instead of using Surovell et al.'s fixed parameteres, the ADMUR approach treats these as parameters to be estimated. Accounting for taphonomy in this manner did not result in adjustments of the ML parameters for the logistic model. This is now briefly mentioned in the text and the results have been included as a supplementary figure.

- Reviewer 1's idea of shoreline dating the 14C-dated sites is a very good suggestion but is complicated by the fact that we have included archaeological radiocarbon dates irrespective of their site-specific contexts. Consequently, a match or mismatch between these distributions would require an in-depth evaluation of the individual radiocarbon dates and sites, which we believe is better done through a separate study that does this in a principled manner. Including such an evaluation here would necessarily involve a rather brief, post hoc evaluation of any identified patterns. That is to say, the suggestion outlines sorely needed testing of the method using radiocarbon dates that are independent of the ones use to derive the method. To address the fact that we do not follow up on this here, we have further underscored some of the limitations and potential biases that hampers the dating method, and the need for principled testing of the method (lines 424-454).

- As per Reviewer 1 we have removed all but one use of cf. (where it is used in the "compare" sense).

- Finally, along with an extended discussion section that highlights limitations and uncertainties with shoreline dating as it is now implemented, we have included a paragraph on the possible bias that could be introduced by activity in the immediate inland (lines 440-454), as pointed out by Reviewer 2. In general, this does pose an important challenge for the applicability and reliability of shoreline dating that is worth highlighting.

Best wishes,
Isak Roalkvam and Steinar Solheim

Decision by Felix Riede, posted 22 November 2023, validated 23 November 2023

Very minor revision

Dear Isak and Steinar,

thank you for submitting you preprint to PCI Archaeology. Reviews have come in and I apologise for the delay in making a decision. Both reviewers are very favorably disposed towards your paper and I would merely urge you to address their minor concerns.

I look forward to seeing a revised version in due time.

Warmly,

Felix

Reviewed by anonymous reviewer 2, 08 November 2023

This is really cool paper! It develops new a new probabilistic approach to create temporal distributions of shoreline dated sites similar to summed probability distributions of radiocarbon dates. In addition, it provides

interesting comparison of 14C-based and shoreline-based date distributions with quite surprising results. I hope that the new tools are also added to the R package.

I only have a couple of comments. First, the difference between RSPD and SSPD is really interesting finding, but I don't think that with your data and analysis, you can conclude that mobility patterns explain this difference. Thus I would be more cautious, when making conclusions. Instead of saying that "SSPD is heavily influenced by mobility", I would say that "SSPD could be influenced by mobility".

Related to this, it would be good to apply taphonomic correction ala Surovell et al to RSPD (implemented in rcarbon). I would assume that after the correction, differences between SSPD and RSPD would be much smaller and that could then indicate that differences are related more to preservational issues rather than mobility. You also acknowledged the possible influence of taphonomic loss, so it might be good to check how big influence the best available correction method would make.

Also it would be good to check the temporal distribution 14C-dated sites either using shoreline dating or by binning the 14C dates so that each site is represented by only one date. This would inform you about how "structurally" similar shoreline dated and 14C dated site samples are. If it turns out that the temporal frequency distribution of sites in 14C-dated sample shows different pattern to shoreline dates sample (increase over time), the differences in SSPD and RSPD may only relate to sampling, i.e. the selection of sites to rather small 14C-dated sample of sites, and not to mobility or time-dependent taphonomic loss of organic (dateable) material.

Finally, a rather minor point: The use of "cf." in citations. I would strongly urge you to avoid using cf. in citations. Its meaning is highly ambiguous. Some people use it as an equivalent to "see also" or "e.g.", which is completely wrong. There are two a bit more correct meanings of "cf." First, it literally means "compare" (in English) and is used in cases where two or more references don't agree on a particular matter: "there are different opinions regarding this (cf. X, Y)". The other usage of "compare" is to indicate that the cited reference disagrees (slightly or strongly) with what you had just written. Because of this ambiguity, it is not good idea to use "cf" basically ever, but at least not as a synonym to "e.g." or "see". In your case (at least "cf. Weninger et al", "cf. Crema", "cf Tallavaara & Jorgensen") the use of "cf" is completely unnecessary.

Reviewed by anonymous reviewer 1, 07 November 2023

Review of

Comparing summed probability distributions of shoreline and radiocarbon dates from the Mesolithic Skagerrak coast of Norway by Isak Roalkvam and Steinar Solheim

The paper by Roalkvam and Solheim reports methodological improvements in shoreline dating of archaeological sites. It provides an exploratory study that compares summed probability distributions (SPDs) of shoreline dates to those of radiocarbon dates from the same area and discusses the implications of the comparison and the detected differences in the SPDs. The paper is well written and a pleasure to read. The title reflects the content of the manuscript well. The abstract is concise and presents the main findings. The Introduction presents all that is required from a good introduction.

I will not attempt to analyze the Bayesian method used by the authors as I lack the required expertise. However, with the knowledge I have of statistics, I found the statistical analyses sound and results credible. Sufficient details are provided for the methods and analysis to allow replication. The figures and graphs are clear and well made.

I commend the authors for not making overly confident claims on how the results should be interpreted and for acknowledging many problems built in the shoreline dating method, thus leaving ample room for further research. It is, however, one such problem that I think should be discussed in more detail, as I think it may potentially have a significant impact on the results and their interpretation. This is the effect that non-shorebound activities and (logistic) mobility from coastal sites to higher elevations may have on site numbers on these higher elevations.

This stems from the indications pointing towards non-shorebound sites, i.e., that there are sites on elevations that suggest an earlier shoreline dating than considered possible for the area, suggesting later non-shorebound activity (L153). As well as from the fact that there are radiocarbon dates indicating later activities at some of the excavated sites, as noted by Roalkvam (2023, "As is also illustrated by the measures for dispersion, some of the sites are situated considerable distances from the shoreline when the dates believed to be erroneous in the original reports are included"). To put it shortly: the paper discusses coastal sites and mentions inland sites, but where are the sites in-between?

This brings us to the peaks in the SPDs presented in figure 5. If we assume that logistic mobility to higher elevations explains a percentage of the sites located in surveys, then the SPDs possibly suggest that when there is a peak in the RSPD there is a corresponding peak in the SSPD some 1500 years earlier, or rather on elevations some 25-50 meters higher than the contemporary shoreline. Could this also explain why there seems to be a decline in site numbers in the SSPD throughout the studied timeframe, i.e., that the number of sites on higher elevations is higher because these areas have been in logistic use for a longer period?

Could it also be that there are certain elevations that have more favorable locations for building a logistic "inland" camp than other elevations? What is the landscape like from this perspective? Can we assume that favorable areas are evenly distributed across all elevations?

Adding a paragraph or two discussing these questions would make the paper even better.

Reference

Roalkvam, I. 2023. A simulation-based assessment of the relation between Stone Age sites and relative sea-level change along the Norwegian Skagerrak coast. Quaternary Science Reviews 299.