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shoredate: An R package for shoreline dating coastal Stone Age sites

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Software

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Summary

As a result of glacio-isostatic rebound, large regions of Fennoscandia have undergone a process of relative sea-level fall following the retreat of the Fennoscandian Ice Sheet. Furthermore, coastal Stone Age sites in the region appear to have been predominantly located on or close to the shoreline when they were in use. Based on their altitude relative to the present-day sea-level, this can be combined with a reconstruction of past relative sea-level change to assign an approximate date to when the sites were in use. This method, called shoreline dating, has been used in the region since the early 1900s (e.g. Brøgger, 1905) and is still widely applied today (e.g. Manninen et al., 2021; Solheim & Persson, 2018).

Statement of need

`shoredate` is an R package developed for shoreline dating Stone Age sites on the coast of south-eastern Norway, based on local geological reconstructions of past relative sea-level change. Drawing on an empirically derived estimate of the likely elevation of the sites above sea-level when they were in use, the method for shoreline dating implemented in the package was recently published in Roalkvam (2023). No open-source software with which to perform shoreline dating currently exists. The only closed-source software available is `sealev` from the University of Tromsø, Tromsø Geophysical Observatory (https://www.tgo.uit.no/sealev/, see Møller, 2003), which can provide non-probabilistic point estimates of shoreline dates based on data last updated in 2002.

`shoredate` is aimed at providing researchers and students dealing with the coastal Stone Age of the region with tools for performing and handling shoreline dates. This complements software for handling radiocarbon dates and other sources of temporal data, such as the R packages `rcarbon` (Crema & Bevan, 2021), `bchron` (Haslett & Parnell, 2008), `oxcAAR` (Hinz et al., 2021), `kairos` (Frerebeau, 2022) and `ArchaeoPhases` (Philippe & Vibet, 2020), as well as closed-source software such as `OxCal` (Bronk Ramsey, 2009).

Shoreline dating is frequently applied in the research and cultural resource management sectors in Norway, both to plan archaeological investigations and for establishing temporal frameworks with which to analyse the archaeological material. Case-studies employing `shoredate` are currently being undertaken. Furthermore, future archaeological material can be drawn on to further test the method as it is implemented here, and potentially lead to adjustments in how it should be applied in a given setting.

Spatial and temporal coverage

As the method of shoreline dating is dependent on reliable reconstructions of relative sea-level change, the package was developed to be applied in the coastal region between Horten in the

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north east to Arendal in the south west (Figure 1). Geologically derived displacement curves from this region have recently been published for Skoppum in Horten (Romundset, 2021), Gunnarsrød in Porsgrunn (Sørensen et al., 2023), Hanto in Tvedestrand (Romundset et al., 2018) and Bjørnebu in Arendal (Romundset, 2018). The spatial coverage of `shoredate` will be extended to surrounding areas as forthcoming data on shoreline displacement becomes available. Furthermore, although the direct applicability of the method in other regions remains undetermined, suggestions and examples of how such extensions can be achieved is included in the documentation for the package.

Following from the latest start date among the geological displacement curves, 9469 BCE marks the lower temporal limit of the package within the spatial limit in south-eastern Norway. The oldest verified anthropogenic activity in Norway currently dates to around 9300 BCE (Glørstad, 2016). In Roalkvam (2023) it was found that sites in the region tend to be located at more variable distances from the shoreline after c. 2500 BCE. This therefore marks the upper temporal limit for shoreline dating in the region.

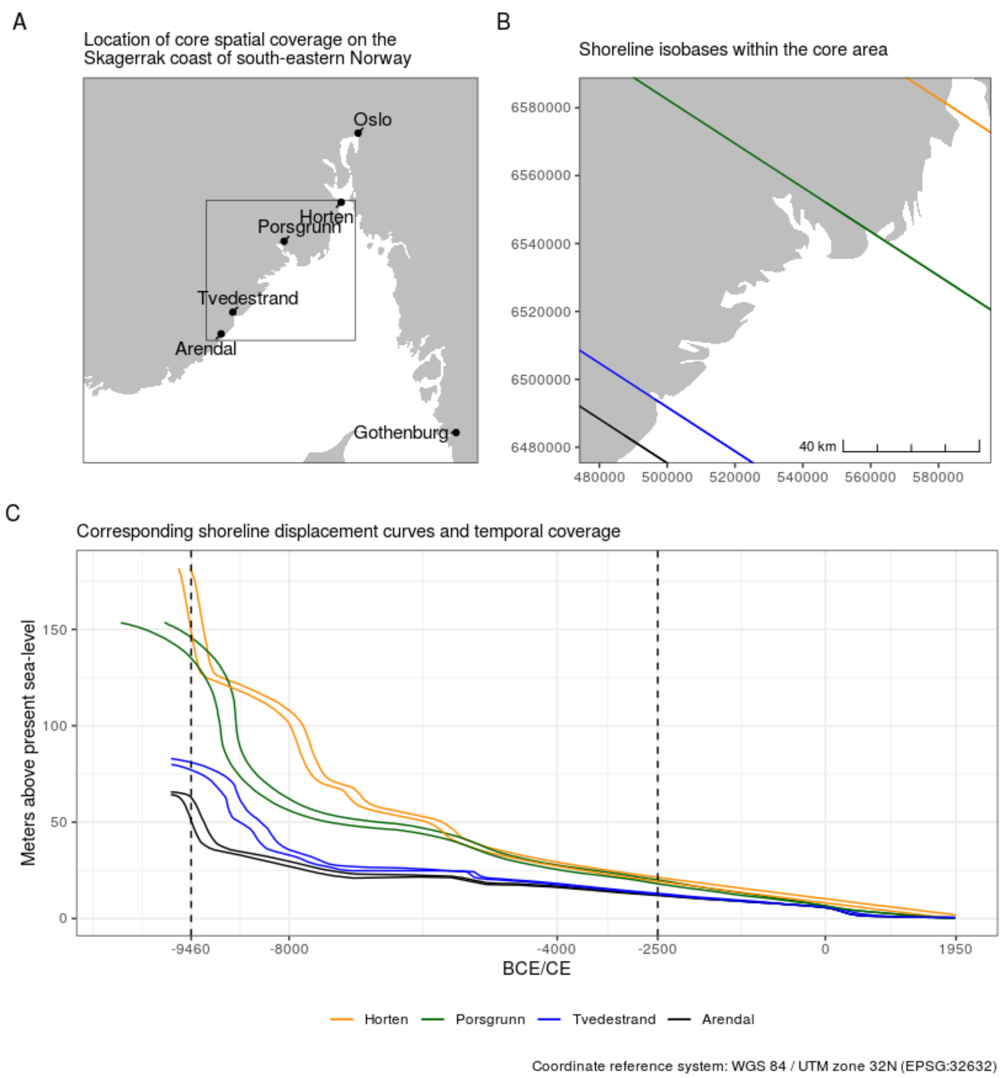

Figure 1: The spatial and temporal coverage for which the package was developed. A) The location of the spatial coverage in south-eastern Norway. B) The location of the isobases that represent contours along which the shoreline displacement has followed the same trajectory. C) The displacement curves corresponding to the isobases, where the temporal limits are marked with dashed lines.

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Example of base functionality

To date a site, its elevation above present sea-level must be provided when running the function `shoreline_date()`. This can be done by either manually specifying the site elevation, or by providing an elevation raster of class `SpatRaster` from the `terra` package (Hijmans et al., 2022) from where this is derived. Unless a pre-compiled curve is provided, the trajectory of shoreline displacement at the location of the site is then interpolated under the hood with the function `interpolate_curve()`, using inverse distance weighting when `shoreline_date()` is called. This is based on the distance between the site and the isobases of the displacement curves. To perform this interpolation, the site geometry has to provided as a spatial object of class `sf` from the `sf` package (Pebesma, 2018).

Figure 2 shows the location of an example site, plotted by passing it to `target_plot()`. Figure 3 displays the result of running the command `interpolate_curve()` on the example site, and plotting the resulting interpolated displacement curve with `displacement_plot()`. Finally, Figure 4 shows the result of dating the example site with `shoreline_date()` when manually specifying that the site is situated at 58.8m above present sea-level. The resulting date is plotted with the function `shoredate_plot()`.

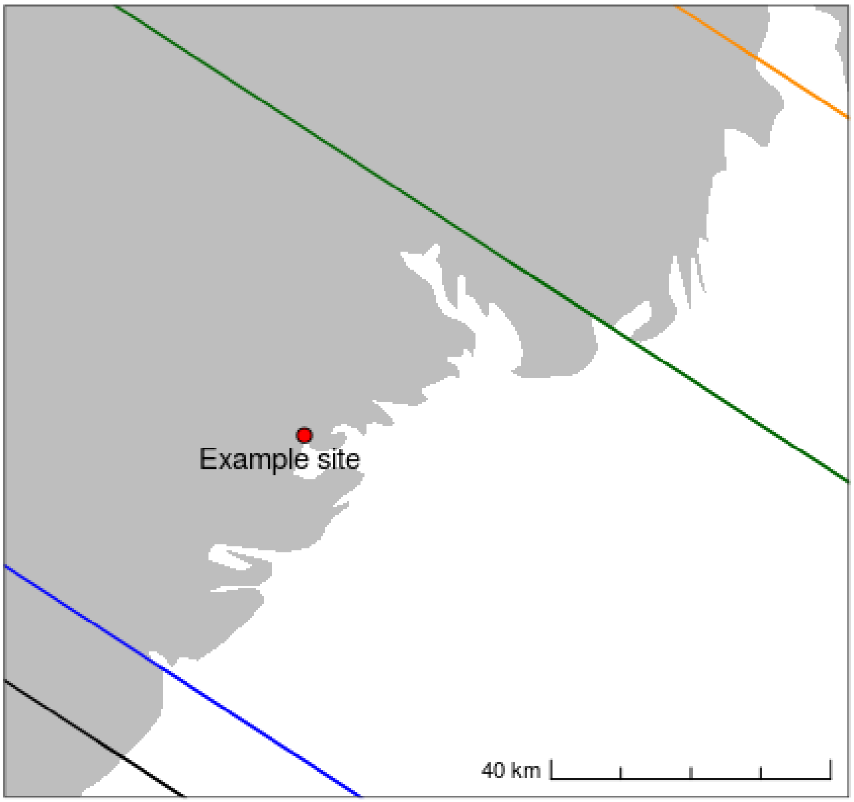

Figure 2: The location of the example site relative to the isobases of the displacement curves. The base map is a simplified light-weight map of the region.

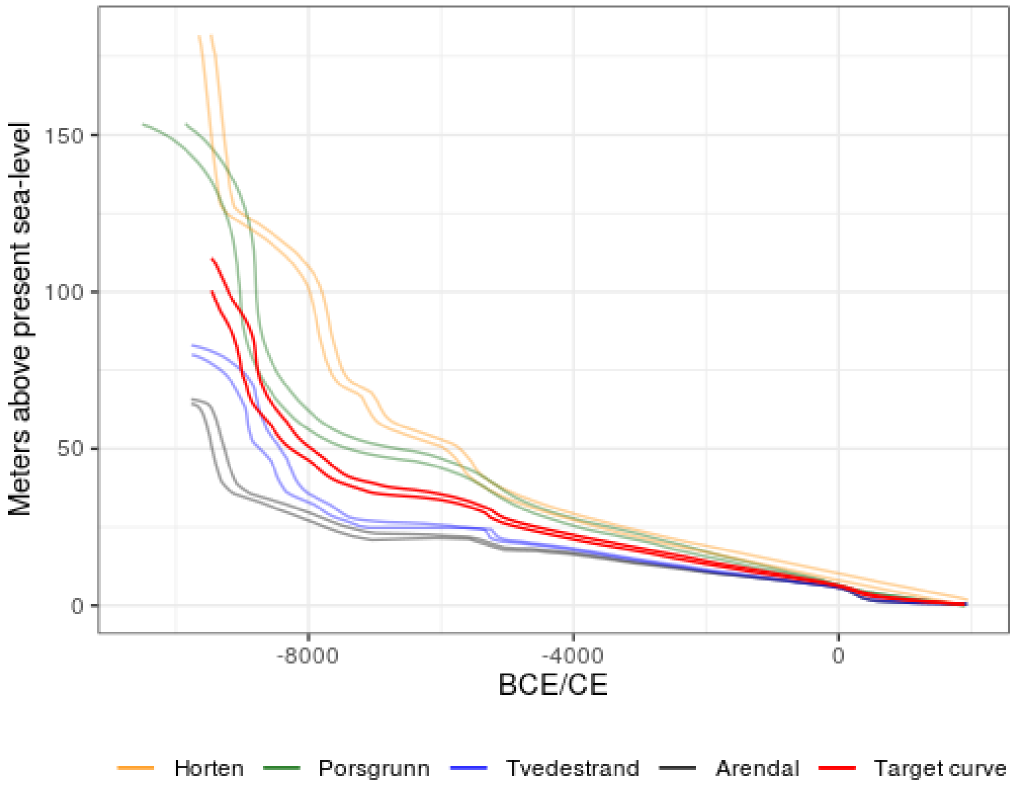

Figure 3: The curve interpolated to the example site by means of inverse distance weighting. This is based on the distance between the site and the isobases of the geological displacement curves.

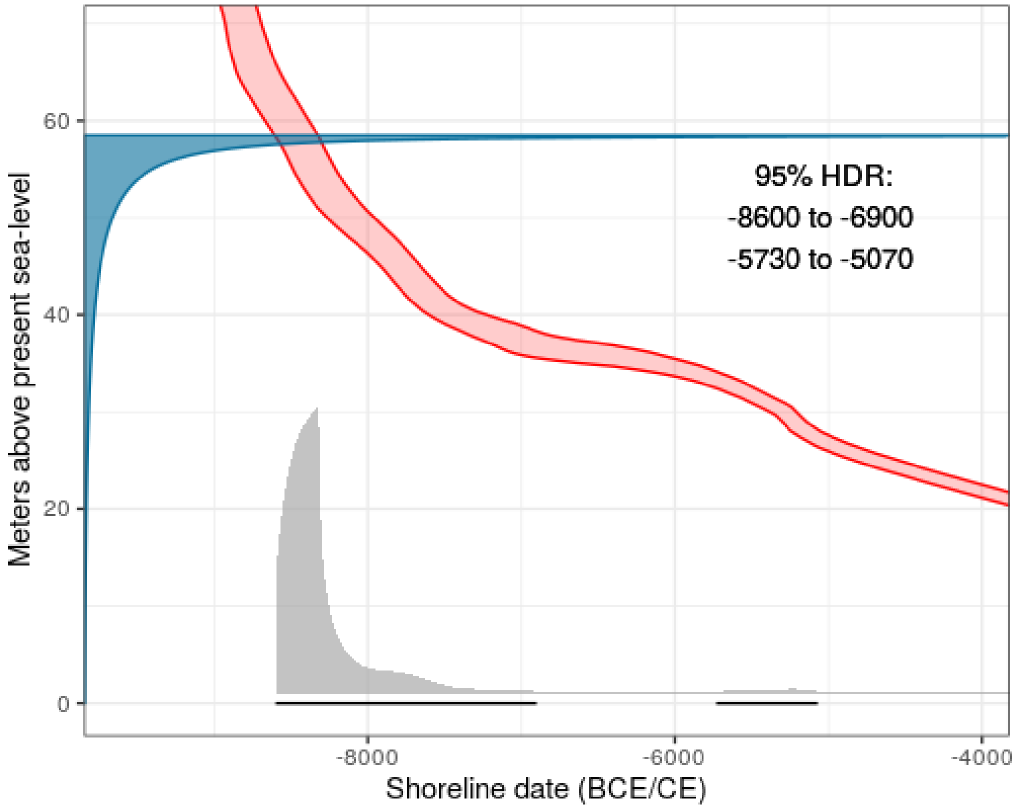

Figure 4: The resulting shoreline date for the example site. The blue gamma distribution on the y-axis indicates the likely elevation of the site above sea-level when it was occupied. The red envelope is the interpolated shoreline displacement curve for the site location. The resulting shoreline date in grey is the result of transferring the probability from the gamma distribution to the calendar scale by coupling it with the displacement curve. The date is underlined with the 95% highest density region (HDR) in black.

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