Computational modelling of the coastal Mesolithic in south-eastern Norway

Isak Roalkvam

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Department of Archaeology, Conservation and History
Faculty of Humanities
University of Oslo

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Summary

Through a series of case-studies that employ Mesolithic data from the Skagerrak coast of south-eastern Norway, this thesis is concerned with contributing to getting a handle on the vast amounts of data that have been and continue to be generated by Mesolithic archaeology in Norway. Fundamental questions concerning the quantity, composition and chronological control we have of the material available to us dictates not only our understanding of the period, but also determines what questions we can hope to answer. This follows from the resolution and quality of the archaeological record, and the varying spatial and temporal scales that different behavioural and societal dynamics operate over. The degree to which the characteristics of our data matches those necessary to illuminate these dynamics thus informs the kind of archaeology we can reliably hope to do.

Given that this data is neither recorded or can be approached without a predefined understanding of what dimensions of it are of interest, the material was explored using a series of heuristic models that are frequently drawn on in the literature to understand prehistoric hunter-gatherer societies and the coastal Mesolithic of Northern Europe. These pertain especially to the dating of the archaeological material, patterns of land-use and mobility, as well as general trends of demographic development.

The thesis consists of four papers and an introductory text. The introductory text establishes the context and motivation for undertaking the studies, relates them to each other, and presents further avenues along which the results can be explored, extended, and potentially be substantiated further. With an aim to make these efforts transparent, reproducible and extendable, the entirety of the project has been undertaken within a framework of open science. This means that all text, figures, data and code is made freely available for anyone to access and scrutinise. Along the same lines, and in part following from the quantitative nature of the derived results, all substantive inferences are instantiated as explicit causal hypotheses in the introductory text. The purpose of this is to promote clear routes for critical engagement and further research efforts.

Some central results from the papers of the thesis follow first from a quantitative assessment of the relationship between coastal Stone Age sites and the contemporaneous shoreline in the region. This largely verified the previously suggested tendency of the sites to have been located close to the shoreline when they were occupied. Following from the quantitative nature of this assessment, this resulted in the development of a new method for shoreline dating Stone Age sites in the region, based on their altitude relative to the present-day sea-level. This method for shoreline dating has been developed as freely available package for the R programming language through the second paper of the thesis, making the method readily accessible for anyone to apply and assess.

The third paper of the thesis focused on approaches for analysing the composition of a larger number of lithic assemblages by structuring the analysis through the use of multivariate statistics. First, this was done to assess the temporal development in the occurrence of artefact types that are in established use in Norwegian archaeology, with the findings largely verifying the current general understanding of these developments. More novel insights follow from the second line of investigation which explored dimensions of the assemblages that have frequently been drawn on outside the Fennoscandian setting to map variation in land-use and mobility patterns associated with the formation of lithic assemblages. Specifically, the volumetric density of lithics on the sites and the proportion of these that have been subjected to secondary modification were found to be negatively correlated. Furthermore, this was also found to follow a temporal development with an increase in the density of lithics and decrease in secondarily worked lithics over time. Drawing on the substantive implications that this relationship has been ascribed in other contexts, the findings could indicate a corresponding overall decrease in occupational duration at the sites through the period. While the relevance of this framework for the Fennoscandian Mesolithic is in need of further substantiation and evaluation, these developments match those previously suggested in the literature concerned with the Mesolithic of south-eastern Norway, giving some additional support for its relevance as a quantitative measure for land-use and mobility patterns in the Fennoscandian Mesolithic.

By drawing on approaches that have been used for analogous treatment of radiocarbon dates, the final paper of the thesis develops a method for assessing the summed probability of multiple shoreline dates with the aim of mapping the frequency distribution of shoreline-dated sites over time. This was then compared to an analysis of the summed probability of radiocarbon dates from within the same area, as both measures have previously been suggested to be related to demographic dynamics. The development of the two proxies diverged, with the frequency of shoreline dated sites following some process of decline through the period and the frequency of radiocarbon dates commencing later than the shoreline dates, and reaching a stable plateau after an initial period of growth. Consequently, while it seems reasonable that both measures hold some demographic signal, the divergence between them would mean that some effects are confounding this relationship. In the paper, it was suggested that mobility patterns is an important determinant for the development in the frequency of shoreline dated sites over time. While mobility patterns were also suggested to impact the frequency of radiocarbon dates, it was proposed that this effect is not as substantial as for the shoreline dated sites. However, properly understanding this relationship will depend on directly assessing the influence of a range of potentially confounding effects.

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Chapter 1

Introduction

For most of its existence, human life has been spent in Stone Age hunter-gatherer societies. Whether inadvertently or not, this past is frequently envisioned as constituting the primordial state of humanity, effectively collapsing it into a more or less dimensionless point of origin. However, the societal variation in this period has been immense and remains not only largely uncharted, but has often remained under-appreciated even within disciplines dealing with past human societies (e.g. Kelly 2013:269–275; Singh and Glowacki 2022). Furthermore, one way to view modernity is as technological and organisational complexification and effectivisation that has led to an ever increasing degree of societal and ecological homogenisation, necessary to meet the increasing energy demands of these systems (Kaaronen et al. 2021). The time-depth of the archaeological record thus gives analytical access to a degree of societal variation that is otherwise unprecedented in human existence, and holds lessons for diverse, localised and long-term human adaptation that is not available for study through anthropological or historical sources. As cultural diversity is argued to facilitate societal systems that are better able to withstand perturbations – much in the same way as biodiversity increases the robustness of ecosystems – this knowledge can be important in a future that we know will bring human societies under increasing degrees of external and internal pressure (e.g. Boivin and Crowther 2021; Burke et al. 2021; Kaaronen et al. 2021).

1.1 Archaeological inquiry and the Norwegian Mesolithic

One way to conceive of scientific inquiry is as a strategy by which we try to confront theoretical constructs with empirical observation, aimed at aligning our beliefs as reliably as possible with what is true (Godfrey-Smith 2003:161). A lot remains to be unpacked from this sentence. However, for now it is enough to note that the empirical side of this equation is a critical point for archaeology, as the fragmented and uncertain nature of the archaeological record means that there will always be a multitude of possible explanations that could account for any observed empirical pattern. Reducing this number of candidate explanations is first and foremost dependent on evidence, which in the case of archaeology are scarce.

Furthermore, as establishing true explanations of a past social reality is at best exceedingly difficult, perhaps impossible, it must be the result of cumulative and recursive efforts from entire research communities over time. Accepting this means that one can adopt a strategy to try to make one's research as open and amenable to scrutiny, extension, criticism and alternative approaches as possible. While easier said than done, an attempt at adopting such a strategy is done here.

To accommodate the above points, this thesis aims to stringently explore and contrast empirical trends that have been deemed important to understand past hunter-gatherer societies, drawing on the extensive material from the coastal Mesolithic (c. 9300–3900 BCE) of south-eastern Norway. Based on this, the project aims to culminate with the generation and presentation of some hypotheses concerning possible causal drivers behind the observed patterns. Exploration and stringency are explicitly voiced here for a couple of reasons. Exploration concerns an aspiration to approach the material with a degree of secession from previous hypotheses concerning the societal developments in the period, and to instead have observed empirical trends dictate the hypotheses presented. This can facilitate a freer investigation of empirical patterns, as it reduces the risk of forcing the treatment, consciously or not, towards a single explanation or end-goal. However, a complete break with previous beliefs is clearly neither possible nor desirable. For one these will in part have dictated how the material under study has been retrieved and recorded, how I will approach it, and is necessary for it to be possible to contextualise and make sense of any observed patterns. Stringency, and with it transparency of the analytical choices made, will make it easier for both me and others to follow the logic of the arguments presented, and make it easier to identify when and in what ways prior beliefs might have led an interpretation astray.

The Norwegian Mesolithic is defined as lasting from c. 9300–4000 BCE, a period in which life was led exclusively has hunter-fisher-gatherers. The material thus represents around 5500 years of mid- to high-latitude hunter-fisher-gatherer adaptation. As in many other areas of the world, the last few decades have seen a dramatic increase in the material generated by Norwegian archaeology. In terms of sheer number of sites and associated data, this is most marked for the coastal Stone Age material (e.g. Bergsvik et al. 2020; Damlien et al. 2021). Furthermore, given that this increase in material is achieved on the back of public spending, it is arguably a disciplinary obligation to utilise this data for research purposes.

While there are many possible arguments for why archaeology is worthwhile at all, some more vague than others, the economic burden of archaeological practice is clearly easier to justify if the data we generate also informs the research we do. However, getting even a basic overview of this now vast material necessitates the use of quantitative and computational methods designed to handle, describe, explore, present, summarise and infer from such quantities of data. Following some early optimism in the 60s and 70s, such methods have, until recently, seen sporadic and relatively limited application for research purposes in Norwegian archaeology (e.g. Prescott 2013).

Quantification offers standardisation and simplification, and by extension scalability and comparability. As with all disciplines concerned with the complexity of social life, whether past or present, archaeology also benefits from multiple perspectives that move between the nuance of particularities and the general trends illuminated by aggregated analysis. I would argue that the latter is at present still underdeveloped in Norwegian archaeology. With renewed and ongoing enthusiasm for such approaches, it is important that this is combined with a continually critical view of the answers these approaches can provide, and those which they cannot.

One of the great disciplinary benefits of archaeology, as compared to other disciplines concerned with the study of human societies, is argued by many to follow from the time depth it offers (e.g. Barton et al. 2012; Gamble 2014; Hodder 1987; van der Leeuw and Redman 2002). Furthermore, while there are instances where the archaeological record allows what could be called glimpses into an ethnographic past of individual lives, the vast majority of the material we have access to is hampered by a degree of temporal uncertainty and mixing of events that necessitates a perspective that is developed to meet the nature and quality of the archaeological record on its own terms (Bailey 2007; Perreault 2019). Both fully utilising the archaeological material and playing to the strengths of the discipline is thus dependent on knowledge of the quality of the material available to us, while also being dependent on developing methodologies fit for handling this data.

1.2 Aims and research questions

The overarching goal of this thesis is to contribute to answering the following:

i) What is the extent and quality of the archaeological record from Mesolithic Norway?

ii) What consequences does this have for our disciplinary agenda and for our understanding of the Norwegian Mesolithic?

The answer to these questions is a disciplinary-wide undertaking, and no single thesis can hope to arrive at a final answer. To contribute to their elucidation, the thesis is centred on three more specific research questions. The first of these can be viewed as largely instrumental in that it pertains to the degree and certainty with which we can fix the occurrence of our data on the calendar scale:

1) What chronological control do we have of the occupation of coastal Stone Age sites within the study area?

As Vandkilde (2007:22) has put it: 'Chronology is the backbone of social interpretation'. Following from an answer to this first question, the following two questions are explored:

2) What general patterns characterises the lithic inventories of the sites over time?
3) How is the frequency of sites distributed over time?

As will be laid out in more detail in later chapters, all three of these questions have built into them assumptions concerning what questions and dimensions of the available data are of interest for our understanding of the Mesolithic in the region, and their answers hold a wide range of potential implications for how the cultural historical developments through the period should be understood.

1.3 Study area

The study area of this thesis is delineated to coastal south-eastern Norway. No strict cultural-historical demarcation to surrounding regions is assumed, nor does that appear to have been the case throughout the Mesolithic.

Furthermore, what is termed the coastal Mesolithic naturally did not exist in isolation from inland regions. While the Mesolithic sites in Norway are concentrated on the coast (e.g. Bjerck 2008), the reason behind the geographical limiting of the study is mainly analytical. First, while Mesolithic data is available from a wider region of south-eastern Norway, including inland areas, the last few decades have seen an virtual explosion of investigations in the coastal region between Horten municipality in the north east to Arendal in the south west (e.g. Damlien et al. (2021), indicated in Figure 1.1). This has also been accompanied by geological studies to map the dramatic sea-level change that has impacted the Norwegian coast through the Holocene (e.g. Romundset 2018; Sørensen, Henningsmoen, et al. 2014). The region thus represents an archaeologically well-sampled area where we also have good control of the trajectory of shoreline displacement. While the findings in the study can be assumed to have relevance for surrounding areas, this subsection of south-eastern Norway therefore limits the spatial extent of the considered data. Furthermore, while this region holds high-quality archaeological material, investigated and recorded using modern methods, there is also an abundance of legacy data from the region, especially in the form of comparatively low-resolution and low-quality survey data. This constrained region thus also offers an excellent case-study for exploring the implications of dealing with data of wildly varying quality.

1.4 Open research and reproducibility

In making the case for open sharing practices in archaeological research, Ben Marwick (2017:426) compares the principle of artefact provenancing with dissemination of raw data and methods that underlie a study. Without any information on the origin of an artefact, its archaeological value is practically none. Comparatively, by openly sharing data and programming code that underlies a study, other researchers can assess the procedures that have led to the results. Apart from facilitating an evaluation of its reliability, this allows others to extend on the analysis and the employed data, to learn and reconstruct how methods are implemented, and to attempt to repeat all or parts of the analysis themselves. Open research is thus beneficial to archaeology as a cumulative research endeavour as it will both increase the frequency of rejection and adjustment of proposed explanations, allow others to explore the foundations and inner workings of these explanations, and because it will increase the pace of method sharing, evaluation and adjustment. While the benefits are clear, Ince et al. (2012:485) have even gone as far as stating that 'anything less than release of actual source code is an indefensible approach for any scientific results that depend on computation'.

Furthermore, making scholarly publications free for anyone to read has been argued by many to lead to a democratisation of the discipline. This will allow non-professionals, prospective students, non-academic collaborators and others without institutional access or the means to pay for access to read the publications (e.g. Lake 2012; Marwick et al. 2017; Marwick 2020). All text, programming code, figures and underlying data associated with this thesis is therefore made freely accessible for anyone.

To this end, this thesis has been written in its entirety using the R programming language (R Core Team 2021). Unlike for example mouse-driven computational analyses, this means that an unambiguous record of the entire analytical pipeline is recorded in the form of programming scripts, moving from the initial loading and cleaning of raw data, through to analysis, visualisation and final reporting of results. Given the large amount of analytical choices that have to made in the course of any analysis, this can never be adequately presented in prose. Furthermore, what a researcher believes they have done need not correspond with what they have actually done. The high-resolution analytical record that is the programming script makes this entirely transparent. All data, programming code, figures and text used in this thesis is freely available in version-controlled online repositories on GitHub (https://github.com/isakro) and on persistent archiving

Figure 1.1: The location of the study area in south-eastern Norway is indicated by the black frame. See the next chapter for a more detailed map and presentation of the study area. The coordinate reference system used throughout this thesis and in the accompanying papers is WGS84 / UTM zone 32N (EPSG: 32632).

Table 1.1: Overview of repositories and pre-prints. GitHub repositories can be accessed by adding the name of the repository after https://github.com/isakro/ in a web browser. Pre/post-prints and archived repositories can be accessed by adding https://doi.org/ before the provided DOIs.

Text	Pre/post-print	GitHub repository	Archived repository
Intro text	NA	thesis	10.17605/osf.io/h3jdf
Paper 1	10.31235/osf.io/3x7ju	assessing.sealevel.dating	10.17605/osf.io/7f9su
Paper 2	NA	shoredate	10.5281/zenodo.7971859
Paper 3	10.31235/osf.io/cqaps	exploring-assemblages-se-norway	10.17605/osf.io/ehjfc
Paper 4	10.31235/osf.io/2f8ph	se.norway.shoredate.14c	10.5281/zenodo.8373857

services where the repositories are provided a digital object identifier (DOI). The repositories for the papers have been organised following the framework of Marwick (2017; Marwick et al. 2018) by use of the related R package *rrtools* (Marwick 2019), while this introductory text has been written and organised using the R package *bookdown* (Xie 2016). Furthermore, Paper 3, which unlike the other published papers is not open access with the publisher, has been uploaded as a post-print to allow for free access. A complete overview with links to the various online archives associated with the individual papers and this introductory text is provided in Table 1.1.

1.5 Overview of papers

1.5.1 Paper 1: *A simulation-based assessment of the relation between Stone Age sites and relative sea-level change along the Norwegian Skagerrak coast*

The first paper of the thesis offers an approach for integrating the various sources of uncertainty associated with reconstructing the relationship between ^{14}C-dated archaeological phenomena and past sea-level change. This is used to quantify the distance between Stone Age sites and the prehistoric shoreline within the study area. That coastal sites would have been located on or close to the prehistoric shoreline is a fundamental premise in Norwegian Stone Age archaeology. In combination with reconstructions of past shoreline displacement, this is frequently used to date the sites based on their altitude relative to the present day sea-level – a method known as shoreline dating. The findings of the paper largely reflect the development proposed in the literature, with a predominantly shore-bound coastal settlement in the Mesolithic, followed by a few sites being located some distance from the shoreline at the transition to the Early Neolithic (c. 3900 BCE) and a more decisive shift with the Late Neolithic (c. 2400 BCE). The result of this analysis is used to propose a formalised method for shoreline dating sites older than the Late Neolithic. This takes into account uncertainty as related to the displacement of the shoreline and the likely distance between sites and the shoreline when they were occupied.

1.5.2 Paper 2: *shoredate: An R package for shoreline dating coastal Stone Age sites*

Based on the findings from the first paper, the second paper of the thesis is a presentation of the R package *shoredate*, which provides tools for performing and handling shoreline dates. The focal point and main functionality of the package is developed for the Norwegian Skagerrak coast, but functionality and guides for extending the package for application in other regions is also provided. The package has been written in compliance with the developmental framework presented by Wickham and Bryan (n.d.), and is made freely available for anyone to install to R from the Comprehensive R Archive Network (CRAN): https://cran.r-project.org/package=shoredate. The paper itself gives a brief presentation of the package, but the publication of software with the *Journal of Open Source Software* also involves a useful and open review process of the source code and associated documentation and user-guides. Having published the package and released it as open source software on CRAN means that the method for shoreline dating is now available for researchers and student to employ, and that underlying code is available for anyone to explore, evaluate, criticise or extend upon. The full details of *shoredate* can be found through the website for the package: https://isakro.github.io/shoredate/.

1.5.3 Paper 3: *Exploring the composition of lithic assemblages in Mesolithic south-eastern Norway*

The second part of the thesis is aimed more squarely at elucidating past cultural history, as opposed to the more instrumental focus of the first two papers, which established tools for improving our chronological understanding of the period. The third paper of the thesis is an exploratory study aimed at identifying variability in the contents of a set of lithic assemblages. The main goals of the paper are to evaluate the typo-technological framework currently in use in Norwegian Mesolithic research, and to assess the temporal development for variables that have been linked to variation in land-use and mobility patterns. It is demonstrated that elements of the so-called Whole Assemblage Behavioural Indicators (WABI, e.g. Clark and Barton 2017) align with previous research into developments of mobility patterns in Mesolithic Norway, suggesting that the WABI could be a relevant framework also in this context. This is specifically reflected in a negative relationship between the density of lithics, and the proportion of secondarily worked lithics in the assemblages over time, which is taken to reflect a transition from a more curated towards an expedient technological organisation with the transition from the Early to Middle Mesolithic (c. 8200 BCE). This is in turn argued to follow from a shift in land-use patterns and an overall reduction in mobility.

1.5.4 Paper 4: *Comparing summed probability distributions of shoreline and radiocarbon dates from the Mesolithic Skagerrak coast of Norway*

Unpacking the complex interplay between environmental conditions, settlement patterns and population density has been deemed of fundamental importance to archaeological inquiry (e.g. French 2016; Shennan 2000). The fourth and final paper of the thesis, written in collaboration with Steinar Solheim, is aimed at combining findings from the previous papers to evaluate the interplay between some empirical indicators suggested in the literature to be related to these dimensions. Concretely, the paper begins the task of elucidating the complex relationship between variation in relative population size as potentially reflected in the frequency of shoreline dated sites and the intensity of radiocarbon dates over time.

The main substantive findings of the paper were that the frequency of shoreline dated sites is relatively high from the start of the Mesolithic, from around c. 9500 BCE, and then undergoes some process of decline. The frequency of radiocarbon dates, on the other hand, only starts from around 8500 BCE and quickly increases along the trajectory of a model of logistic growth. This increase has plateaued by the first centuries after 8000 BCE, and then remains stable for the duration of the Mesolithic. In the paper, we suggest that the different behaviour of the proxies reflect that the frequency of shoreline dated sites is more heavily influenced by variation in mobility patterns, compared to that of radiocarbon dates, which we suggest is more heavily determined by population density. Clarifying this relationship will, however, depend on drawing on other measures that track the developments of factors such as mobility patterns that we suggest cause the discrepancy between the proxies.

The paper has been released as a pre-print (see Table 1.1) and been submitted for open peer review at Peer Community in Archaeology (see https://archaeo.peercommunityin.org/PCIArchaeology for more information).

1.6 Structure of the thesis

This introductory text is divided into six chapters, which contextualises the individual papers and point towards some future avenues along which these can be extended upon. The introductory text is followed by the four papers and the appendices associated with these.

Following this introduction, the next chapter lays out the environmental and archaeological background for the Mesolithic in the study region. Chapter 3 presents the major analytical perspectives that underlie the undertaken studies and the research questions that are posed. Chapter 4 lays out a more foundational strategy for archaeological inquiry in the form of model-based archaeology, which I believe offers a valuable framework for both understanding the contribution of the individual papers and how these can be developed further. In Chapter 5 the papers are then cast within this model-based framework, both to clarify the arguments that underlie them, and to point out some future directions for how these can be fruitfully extended upon. The final chapter concludes by summarising the overarching contributions of the thesis.

Chapter 2

The Mesolithic in south-eastern Norway

This chapter presents the context of the study, beginning with the overarching environmental developments relevant to the Mesolithic of south-eastern Norway, before general archaeological understandings and discussions of the period are presented. Focus is on the developments in the coastal areas of south-eastern Norway, but insights from studies undertaken in Norway and Fennoscandia more widely will be drawn on at times. The location of the study area is given in Figure 2.1 (see Figure 1.1 for a map displaying the location of the study region within Northern Europe).

2.1 Environmental setting

The environmental setting for the Mesolithic in Scandinavia is first and foremost defined by the end of the last glacial period with the transition to the Holocene around 9700 BCE, following the end of the Younger Dryas cold period (Mangerud and Svendsen 2022; Skar and Breivik 2018). This was caused by changes to the Earth's orbital parameters that led to an increase in solar irradiance (e.g. Berger and Loutre 1991). Most pronounced of the resulting interrelated environmental developments is the melting of the Fennoscandian Ice Sheet, corresponding relative sea-level change, changes in atmospheric and oceanic circulation impacting temperature and precipitation, as well as the developments of the Baltic Sea, which has transitioned between being open and closed off from the ocean (see Figure 2.2).

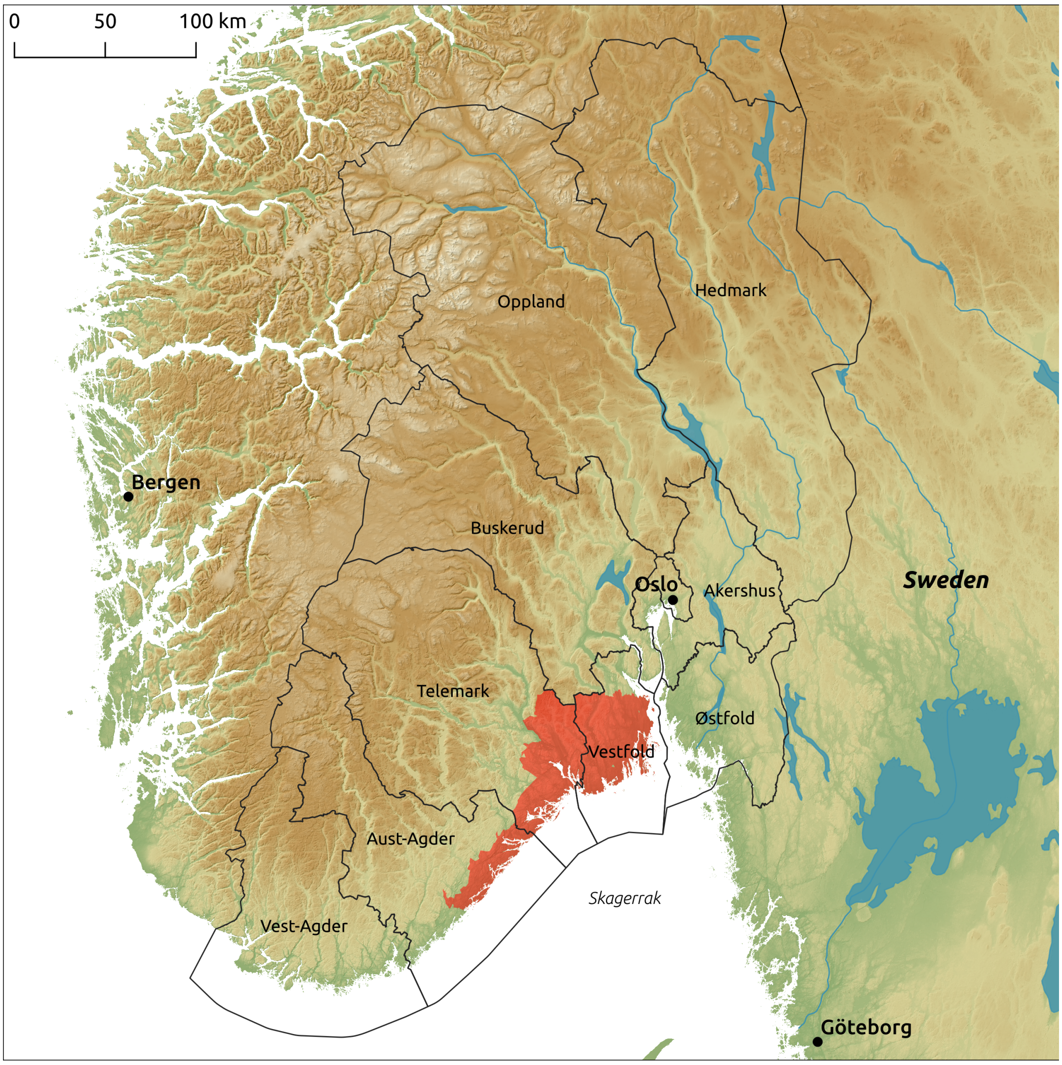


Figure 2.1: Overview of study area. The red area marks where the material directly studied in this thesis stems from (see individual papers for details), defined here by the borders of the municipalities from where the material originates. The counties outlined in black make up the administrative region of the University of Oslo, the Museum of Cultural History. The counties are given as they were defined before 2020, when several of these were combined due to administrative changes. The coastal region from around Göteborg to Vest-Agder is usually considered relatively uniform in terms of material culture throughout the Mesolithic.

2.1.1 Climate

Climate reconstructions for the northern hemisphere based on oxygen isotopes from the Greenland ice cores indicate gradually increasing temperatures from the end of the Younger Dryas c. 9700 BCE (S. O. Rasmussen et al. 2014), the onset of which generally corresponds, possibly with a slight time-lag, with developments in Fennoscandia and Norway (Lohne et al. 2013, 2014; Manninen et al. 2018; Säppa et al. 2009). This warming trend is interspersed by a few abrupt climate reversals, mainly caused by freshwater-forced weakening of thermohaline oceanic circulation. The first of these is the Preboreal oscillation (PBO) around 9400 BCE (Björck et al. 1997), followed by the Erdalen event indicated by glacial re-advances c. 8400 BCE and 7700 BCE (Nesje 2009). The most pronounced of the cooling events occurred c. 6200 BCE (the 8.2ka event Säppa et al. 2009; Wiersma and Renssen 2006; correlating with the Finse event identified in glacial records, e.g. Nesje et al. 2005). Although these are the most marked events, sediment cores from the North Atlantic also indicate more environmental fluctuations through the rest of the Holocene than what is indicated in the Greenland ice cores (Nesje et al. 2014:244).

Pollen-based reconstructions from Northern Europe indicate that the trend of increasing temperatures reached the local Holocene thermal maximum c. 6000–2800 BCE, which is around 2000 years later than what is indicated in the Greenland ice cores (Säppa et al. 2009; see Sørensen, Høeg, et al. 2014; Wieckowska-Lüth et al. 2017 for south-eastern Norway), likely reflecting a difference between regions primarily influenced by orbital forcing and those affected by the presence of melting ice sheets (Renssen et al. 2009). This warming trend is evident from a range of records, including glacial fluctuations, where Scandinavian glaciers reached their most contracted state around 4600–4000 BCE (Nesje 2009). Furthermore, as the altitudinal tree limit is reflective of thermal conditions, the dating of subfossil pine stems can provide a minimum indicator for this climate proxy. The altitudinal limit of pine (*Pinus sylvestris*) in the area of the Hardangervidda mountain plateau in central southern Norway was significantly higher than at present from the Late Boreal and through most of the Atlantic period. When adjusted for isostatic uplift, the limit reached its highest point at upwards of 240 m above the present limit in the period c. 5200–4200 BCE (Dahl and Nesje 1996). From around this point on the temperatures decline, with some fluctuations, towards the present, and the climate was increasingly characterised by being colder, wetter and more unstable (Säppa et al. 2009), also indicated by a decline in pine-tree limits and the reforming and re-advance of glaciers from c. 4000 BCE (Bjune et al. 2006; Dahl and Nesje 1996; Nesje 2009).

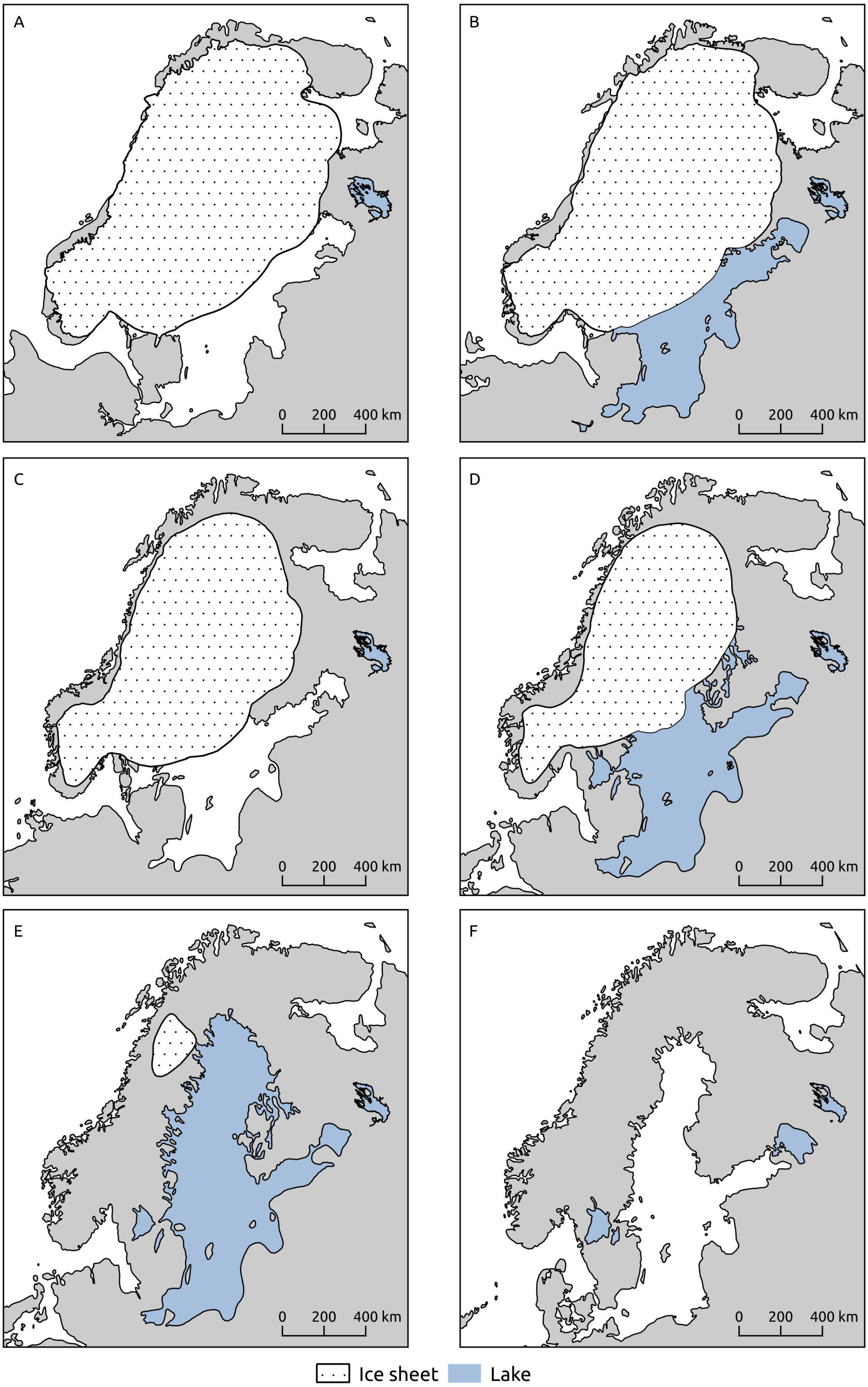


Figure 2.2: Overall trends of deglaciation, relative sea-level change and the Baltic Sea stages. A) Younger Dryas, c. 10,700–9700 BCE; B) Early Preboreal, c. 9700–9200 BCE; C) Late Preboreal, c. 9200–8700 BCE; D) Early Boreal, c. 8700–8000; E) Late Boreal, c. 8000–7200 BCE; F) Late Atlantic, c. 6500–4500 BCE. Data from the European Prehistoric and Historic Atlas, Centre for Baltic and Scandinavian Archaeology (https://zbsa.eu/), with further references therein.

2.1.2 Sea-level change and deglaciation

The colloquial understanding of the term sea-level generally equates to what is typically termed the relative sea-level in geology, denoting the elevation of the sea relative to land, or, more formally, the difference in elevation between the sediment surface of the Earth and the mean sea-level (otherwise known as the geoid) when measured with reference to the Earth's centre (Mitrovica and Milne 2003; Shennan 2015:7). Continental ice sheets have been the primary determinant for relative sea-level variation through the Quaternary (Milne 2015; Milne and Shennan 2013). First, these effects follow from mass that is gained and lost from ice sheets with accumulation and ablation. The exchange of mass between the ocean and ice sheet impacts the eustatic or ice-equivalent sea-level. The eustatic sea-level is defined as the sea-level if the ocean water had been evenly distributed across a non-rotating rigid earth, without accounting for gravitational effects (Shennan 2015:6). At the end of the last glacial period, especially the melting of ice sheets in North America, Northern Eurasia and of the enlarged ice sheets in Greenland and Antarctica caused a rapid increase in the eustatic sea-level (e.g. Steffen and Wu 2011). However, non-eustatic effects impact the relative sea-level at all locations on Earth, and no location is therefore likely to directly reflect the eustatic sea-level (Shennan 2015). Put differently, the eustatic sea-level is not directly measurable, as the impact of ice sheets, as well as tectonic crustal movement and water salinity and temperature will variably impact the relative sea-level at any given location (Milne and Mitrovica 2008).

The varying weight of ice sheets leads to adjustments in the lithosphere, called glacial isostatic adjustment (GIA), following from mass loading and unloading that causes the viscous mantle and elastic crust of the Earth to subside with increased weight and lift upwards with reduced weight. The mass of the ice sheet also impacts the gravity field, and the mass of the ice sheet determines its gravitational pull on surrounding seawater. These effects have thus been most marked in so-called near-field areas, that is, areas that have been covered by the ice. In their categorisation of the ocean into zones based on major characteristics of post-glacial relative sea-level change, Clark et al. (1978) classify zone I as areas that have been subject to a monotonic relative sea-level fall, as they have been dominated by these effects after the retreat of the ice.

In areas peripheral to near-field regions of class I, the collapse of an ice sheet and rebound of near-field areas will cause depression of the so-called forebulge. The forebulge is a result of visco-elastic uplift of the lithosphere peripheral to the depressed regions (e.g. Mitrovica and Milne 2002; Steffen and Wu 2011:191–194). With the collapsing forebulge, regions of class II have experienced continuous submergence. As the effects that distinguish zone I and II are dependent on the distance to the ice sheet, there is a transitional zone between the two that has been impacted by an initial emergence of land, followed by submergence, where the degree of emergence contra submergence is higher closer to the ice margin (Clark et al. 1978). The Fennoscandian forebulge has been found to have had a maximum magnitude of c. 60 m, and to have been located around 100 km from the maximum extent of the ice sheet (Fjeldskaar 1994), possibly with some migration, placing it offshore from Norway and well into the European mainland (Steffen and Wu 2011:191–194). The Fennoscandian forebulge is thus of limited relevance to the areas dealt with in this thesis.

In contrast to near-field areas, relative sea-level change in far-field regions is more heavily determined by eustatic sea-level change, which has thus generally led to inundation of these areas with the melting of continental ice sheets. However, the relative sea-level in far-field areas do also show deviation from the eustatic sea-level (Milne and Mitrovica 2008). Some of these effects are more subtle, such as so-called ocean siphoning where the collapse of forebulges and hydro-isostatic depression of ocean floors causes water to migrate to fill the vacated spaces, and continental levering where an increased water load cause oceanic regions to subside while continental shelves flex upwards (Mitrovica and Milne 2002). Finally, GIA induced variation in Earth's rotation and gravitational attraction can also substantially impact the relative sea-level by impacting the configuration of the geoid. The geoid, or geodetic sea-level, is the equipotential surface of the Earth's gravity field, which is affected by differences in the density, flow patterns and structure of the Earth which impacts its rotational vector (Milne and Mitrovica 1998; Mörner 1976). While these effects can influence all areas on Earth, they are especially defining of the non-eustatic signals in far-field regions.

The relative sea-level is thus mainly the result of eustatic, isostatic and geoidal effects, in addition to thermosteric effects on the salinity, temperature and thereby the density of the ocean water, where different locations and points in time have been differentially impacted by these effects. At the Last Glacial Maximum, c. 20,000 BCE, around 5.5% of the world's water was bound in ice, compared to 1.1% today. Around one seventh of this was in turn bound in the Fennoscandian Ice Sheet (Steffen and Wu 2011). As a result, relative sea-level change in Fennoscandia has been dominated by GIA effects (see Figures 2.2 and 2.3). Mörner (1979) described the Fennoscandian uplift in terms of a cone that roughly corresponds with the extent and variable weight of the ice sheet, where the intensity of uplift has intensified along a gradient towards the centre of the cone. This is centred on the coast of the Bothnian Bay around the city of Umeå in Northern Sweden, where the uplift has had the highest magnitude, with dissipating uplift moving out from this centre. Although the intensity of uplift has varied substantially throughout prehistory, with the influence of GIA gradually dissipating, the relative intensity of uplift has roughly, although with some variation (see e.g. Sørensen et al. 1987), corresponded with the present-day direction of the uplift gradient given in Figure 2.3 (see Steffen and Wu 2011; Vestøl et al. 2019; cf. Mörner 1979:Figure 26).

As a result of the GIA, the study area for this thesis falls within the class I zone of Clark et al. (1978), characterised by a continuous and still on-going sea-level regression. In areas of Fennoscandia more peripheral to the centre of uplift in the Bothnian Bay, the sea-level fall has been comparatively less stark, been subject to periods of sea-level transgression, and in the outer-most periphery, inundation (e.g. Lohne et al. 2007; Romundset et al. 2011, 2015; Svendsen and Mangerud 1987, cf. Figure 2.2).

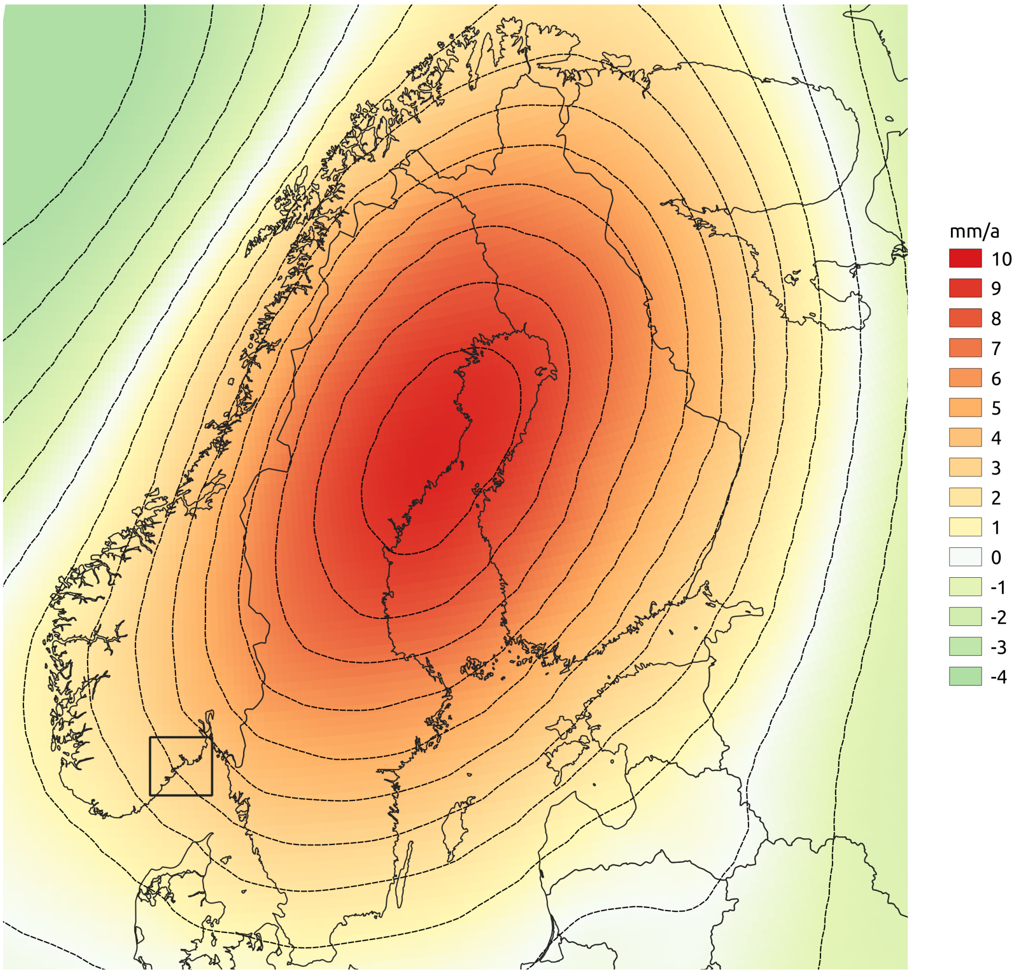


Figure 2.3: Present annual absolute uplift in Fennoscandia relative to the Earth's centre of mass. Note that the absolute uplift is independent of the relative sea-level, which is also determined by other effects. The location of the study area of this thesis is outlined with a black frame. Data from the official land uplift model NKG2016LU of the Nordic Commission of Geodesy (Vestøl et al. 2019).

The development of relative sea-level change within the study area is given by shoreline displacement curves in Figure 2.4. This development has been quite dramatic, which can be illustrated by reference to the marine limit in the region. The marine limit is the highest post-glacial elevation of the shoreline. The highest known marine limit in Fennoscandia is around 286 meters above present sea-level (masl) at Skuleberget in Ångermanland in east-central Sweden (Berglund 2012). Comparatively, the marine limit is around 220 masl in the innermost part of the Oslo fjord. In Horten, at the northern limit of the study area for this thesis, the marine limit is c. 182 masl (Berg-Hansen et al. 2022; Romundset 2021, Figure 2.4). In the centre of the study area, in Porsgrunn, the marine limit is around 155 masl (Sørensen, Henningsmoen, et al. 2014), and furthest to the south, in Arendal, around 70 masl (Romundset et al. 2018). These differences show the gradient in the earliest post-glacial shoreline, resulting from differential loading of the ice sheet.

2.1.3 Flora

The increases in temperatures led to a transition from Arctic to Boreal vegetation in the early Holocene of south-eastern Norway, with a succession from pioneer species of bushes and grasses, to the establishment of open birch forest towards the end of the 10th millennium BCE (Birks 2015; Høeg et al. 2018:194). This was followed by the marked spread of hazel (*Corylus avellana*) and pine c. 8500–8000 BCE, with elm (*Ulmus glabra*) and oak (*Quercus robur*) following a few hundred years later (Høeg et al. 2018; Sørensen, Høeg, et al. 2014:202). The spread of various deciduous trees increased in the Atlantic period, and from around 5500 BCE there was a marked increase in oak as well as the introduction of linden (*Tilia cordata*), the most heat-demanding of these tree-species (Høeg et al. 2018:199).

There is also some regional climatic variation in the present-day coastal areas of south-eastern Norway. The inner, more sheltered parts of the Oslo fjord has a more continental climate, characterised by cold winters and warm summers in which most of the precipitation falls. Towards the distal coastal areas the climate is more oceanic in character, with comparatively warmer winters with more precipitation and somewhat colder summers than in the inner coastal areas – differences that also impact vegetation (Hafsten 1956:16–29).

A note should also be made here that anthropogenic influence on vegetation cover in the Mesolithic is evident from palynological indicators of fire management at some sites (e.g. Selsing 2016; Wieckowska-Lüth et al. 2018), and is possibly also related to the spread of hazel through foraging of hazel nuts (Høeg et al. 2019:105–109). However, human-induced changes to vegetation is most pronounced towards the end of the Neolithic with the wide adoption of agriculture (e.g. Hjelle et al. 2018; Høeg et al. 2018:199; Wieckowska-Lüth et al. 2018).

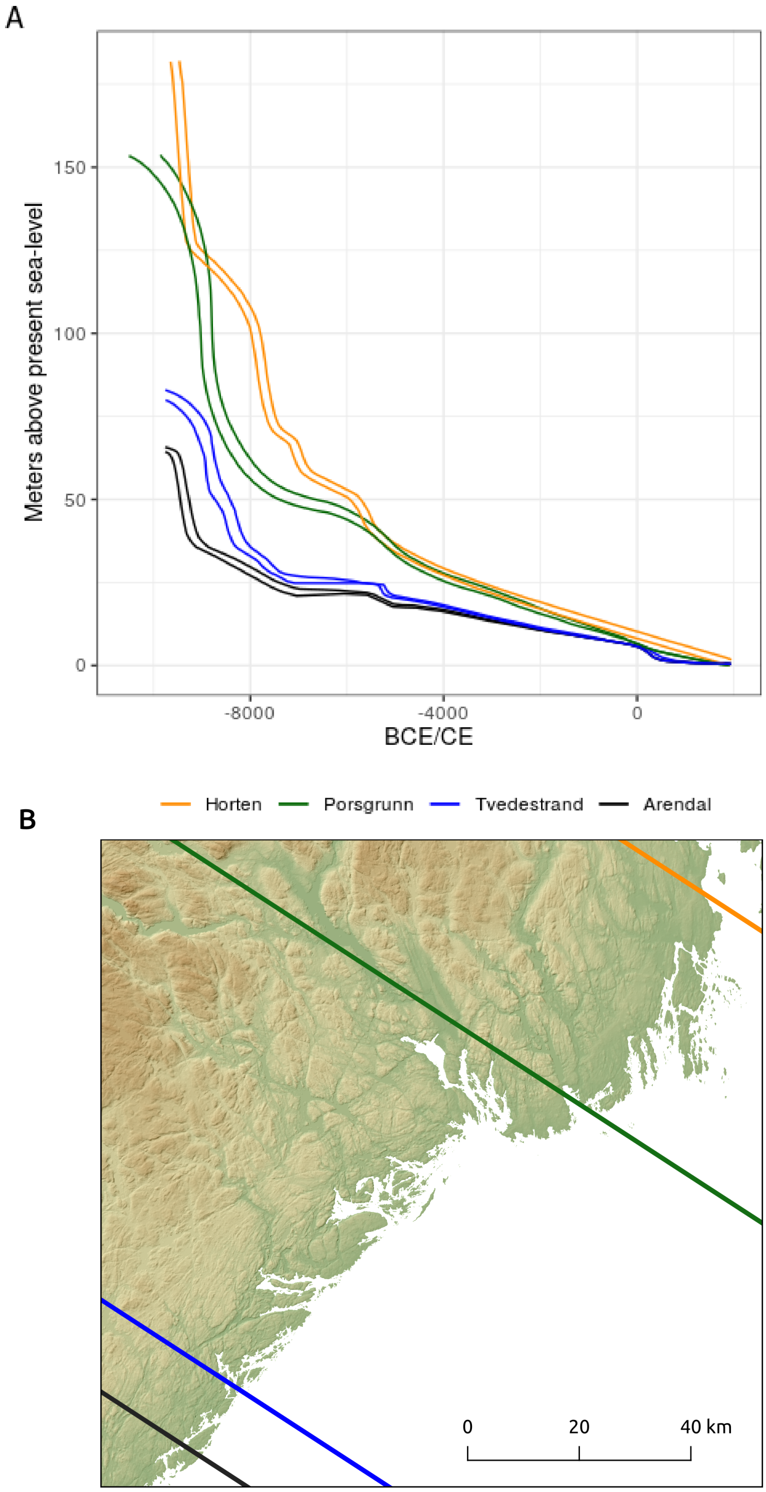


Figure 2.4: Relative sea-level change in the study area in south-eastern Norway (see Figures 1.1 and 2.3 for an overview of its location). A) Shoreline displacement curves for Horten, Porsgrunn, Tvedestrand and Arendal. B) Location of the isobases corresponding to the displacement curves. The isobases represent contours along which the relative sea-level change has followed the same trajectory.

2.1.4 Palaeoceonography

An important driver for oceanic and climatic conditions in Norway is the Norwegian Atlantic Current (NwAC), a surface current which carries warm saline waters along the outer Norwegian coast as an extension of the North Atlantic Current. As there is a close connection between atmospheric conditions and upper ocean systems, developments in sea surface temperatures (SST) in the Norwegian Sea correspond with general climatic shifts (Berner et al. 2010). At the transition from the Younger Dryas to the Preboreal there is a rapid increase in SST with increased inflow of Atlantic water, which is characteristic of the conditions through the HTM (Andersen et al. 2004). This trend is also impacted by the cooling PBO, and the Erdalen and Finse events (Berner et al. 2010; T. L. Rasmussen et al. 2014). From around 2500 BCE there is a general transition towards lower SST, which is characteristic for the Norwegian Sea for the remainder of the Holocene (Andersen et al. 2004).

Zooming in to the palaeoceonographic developments in Skaggerrak, Gyllencreutz et al. (2006) identify four major developmental stages. From the period 13,000–11,000 BCE, Skagerrak is a large fjord, open to the west and enclosed by land to the south and the ice-front to the north. Warmer Atlantic water impacts Skagerrak already from the start of this period, but the circulation in Skagerrak is likely to have been weak. At around 11,000 BCE, drainage started from the Baltic Sea, at this stage the Baltic Ice Lake, through the Öresund strait to the south (Andrén et al. 2011, see Figure 2.2A). Due to the difference in elevation, this involved a unidirectional outflow of glacial melt-water from the Baltic Ice Lake through the Öresund strait, until the final drainage of the ice lake around 9700 BCE. The resulting Baltic Sea stage, which thus corresponds with the onset of the Holocene epoch, is termed the Yoldia Sea. While the Yoldia Sea had open contact with Skagerrak through straits in south-central Sweden through Lake Vänern and the area around and north of Göteborg, it would take c. 300 years before saline water could enter through the narrow straits (Andrén et al. 2011, indicated in Figure 2.2B and 2.2C). Due to isostatic uplift, the Baltic Sea was again closed off from the ocean around 8700 BCE, marking the onset of the Ancylus Lake stage, in which the Baltic sea was a large freshwater lake until c. 6900 BCE (Figure 2.2D and 2.2E).

In the period from 7500–6000 BCE, the present-day circulation patterns are established in Skagerrak. The opening of the English Channel and the isolation of Doggerbank in the North Sea, starting from around 8000 BCE–7000 BCE, resulted in an increased Atlantic inflow to Skagerrak, and in the period from around 8100–6900 BCE the gradual eustatic opening of the Öresund and Danish Straits established an opening to the Baltic Sea in the south, marking the onset of the Littorina Sea stage (Figure 2.2F). In combination, these developments lead Gyllencreutz et al. (2006) to consider most major features of the current circulation system in Skagerrak to have been established by c. 6500 BCE (see Figure 2.5, and Christensen et al. 2018).

While the inner parts of the Oslo fjord are sheltered from Skagerrak today, this has followed from relative sea-level change. In addition to a different configuration of the secondary fjord system and different positions for river run-offs, the fjord itself would have been a larger bay in the earliest part of the Holocene. This has implications for the circulation and salinity of the inner-most parts of the fjord, which would have been more exposed to Skagerrak (Staalstrøm et al. 2021) and which would also have had implications for the climatic conditions that today differentiate the inner and outer parts of the fjord (cf. Hafsten 1956).

2.1.5 Fauna

The above developments have framed the population dynamics of terrestrial and marine fauna in south-eastern Norway through the Mesolithic, where the transition from Arctic to more temperate conditions led to the displacement of cold-tolerant terrestrial species, and the salinity and temperature of Skagerrak similarly impacted marine species (e.g. Boethius 2018a; Breivik 2014; Damlien et al. 2021:24; Jonsson 2014; Mansrud and Persson 2018; Sørensen, Høeg, et al. 2014).

In the transition towards a Boreal climate, terrestrial Arctic species such as reindeer (*Rangifer tarandus*) and polar fox (*Alopex lagopus*) moved to the mountainous regions, while species such red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*), elk (*Alces alces*), beaver (*Castor fiber*) and wild boar (*Sus scrofa*) increasingly populated the forest-covered landscape in the lower lying areas (Hufthammer 2006; Jonsson 1995). Aurochs (*Bos primigenius*) and European bison (*Bison bonasus*) reached at least as far north as central southern Sweden, but likely disappeared with the opening of the Öresund and Danish Straits (Hallgren 2018).

Following the retreat of the ice, the spread of cold-resistant marine fauna compatible with low ocean salinity would have been more rapid than that of terrestrial species (Jonsson 2014). Important drivers of Late Holocene bio-productivity in Skagerrak has been nutrient-rich terrestrial inflow from flooding and river run-offs, internal release of nutrients through upwelling, and external influx of nutrients from Baltic and Atlantic waters (Fonselius 1996; Polovodova Asteman et al. 2018), which is related to the strength and salinity of inflow from the Atlantic Ocean and outflow of brackish water from the Baltic Sea. Comparatively, the influence of the melting ice sheet in the Preboreal, and the constrained outflow and strong tidal current from the Baltic Ice Lake through Lake Vänern, has been argued to have given rise to large amounts of primary phytoplankton in Skagerrak in this period.

This would in turn have attracted fish, where the early presence of capelin

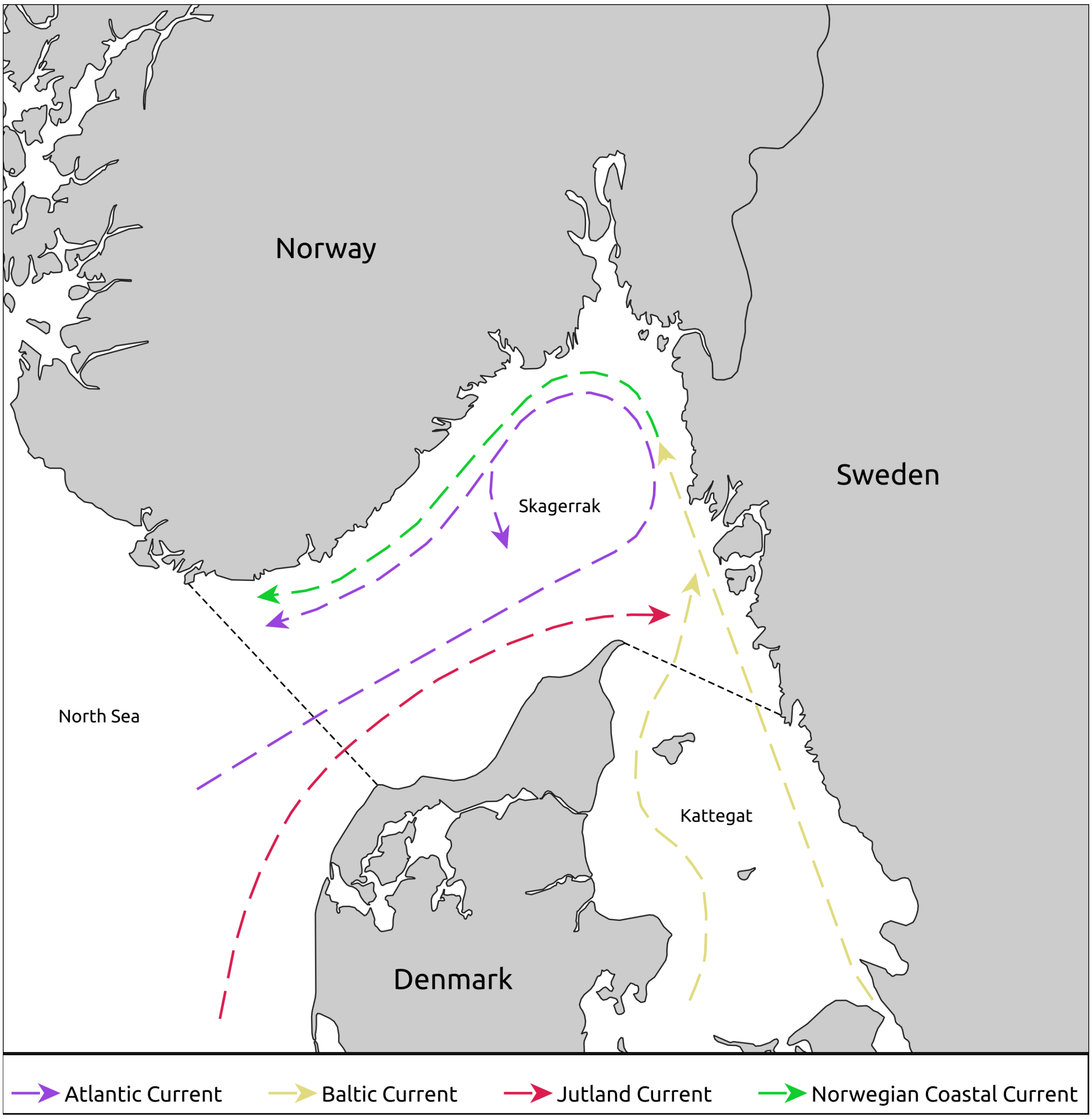


Figure 2.5: Main currents in present-day Skagerrak (redrawn after Staalstrøm et al. 2021:fig.5, see also Christensen et al. 2018).

(*Mallotus villosus*) has been highlighted (e.g. Jonsson 2014; Sørensen, Henningsmoen, et al. 2014), which would have quickly populated these areas and could form the dietary basis for whales such as the fin whale (*Balaenoptera physalus*) and humpback whale (*Megaptera novaeangliae*), seals such as ringed seal (*Phoca hispida*) and harp seal (*Phoca groenlandica*), and predatory fish such as polar cod (*Boreogadus saida*), cod (*Gadidae*), and cusk (*Brosme brosme*). With the reduced inflow of glacial melt-water and the closing off of the Ancylus Lake in the Boreal, this could have led to a reduction in primary biomass, in turn impacting the abundance and composition of marine fauna (Jonsson 1995, 2014; Sørensen, Henningsmoen, et al. 2014; see also Boethius 2018a; Breivik 2014; Mansrud and Persson 2018), with e.g. herring (*Clupea harengus*) preferring warmer waters than the capelin. Furthermore, freshwater fish such as pike (*Esox lucius*) and perch (*Perca fluviatilis*) eventually reached Eastern Norway through river systems from the Ancylus Lake, and anadromous species such as trout (*Salmo trutta*), salmon (*Salmo salar*) and Arctic char (*Salvelinus alpinus*) also migrated along the coast (Jonsson 1995; Refseth et al. 1998). Furthermore, it has also been suggested that humans transported trout to establish these populations in rivers and lakes in the mountainous regions already in the Mesolithic – with the species being present from at least the 5th millennium BCE (Mjærum 2016; Mjærum and Mansrud 2020).

2.2 Archaeological background

Having presented the general environmental developments of the period, the following section gives an outline of how chronological and societal developments in the Mesolithic of south-eastern Norway have been characterised and understood archaeologically. As outlined by Bjerck (2008:61), the first focused research on the Norwegian Mesolithic is ascribed to Hansen (1904), who studied the material that A. W. Brøgger (1905) later saw as a defining element of the Nøstvet culture. In 1909, Nummedal made discoveries of flint artefacts in western Norway that were deemed likely to have an earlier date than the Nøstvet material, and which led to the definition of another cultural unit termed Fosna (Nummedal 1923). Nummedal later also discovered material in northern Norway that had parallels with, but was considered distinct from Fosna and was given the label Komsa (Nummedal 1926). While the geographical and temporal relationship between these cultural units were recognised as unresolved and was subject to much debate, the common understanding was for many decades that southern Norway was defined by the chronologically sequential phases Fosna and Nøstvet, while Komsa was seen as defining of the entire Mesolithic period in northern Norway (see e.g. Indrelid 1978:147).

Table 2.1: Chronological framework. Glørstad's (2010) divison of phases reflects the more traditional framework, to which Reitan (2016, 2022) has recently suggested considerable adjustments.

Glørstad (2010)	
Early Mesolithic, Fosna phase	9300–8200 BCE
Middle Mesolithic, Tørkop phase	8200–6300 BCE
Late Mesolithic, Nøstvet phase	6300–4600 BCE
Late Mesolithic, Kjeøy phase	4600–3800 BCE
Reitan (2022)	
Single-Edged point phase	9300–8600 BCE
Høgnipen point phase	8600–8300 BCE
Microlith phase	8300–7000 BCE
Pecked adze phase	7000–5600 BCE
Nøstvet adze phase	5600–4500 BCE
Transverse arrowhead phase	4500–3900 BCE

With renewed debates in the 1970s, that were arguably founded on a better understanding of lithic technology (Bjerck 1994), significant alterations to the chronological framework was proposed. Mikkelsen (1975a) suggested a quadripartite division of the Mesolithic in south-eastern Norway by dividing the period into the Early Mesolithic Fosna phase, the Middle Mesolithic Tørkop phase, and the Late Mesolithic phases Nøstvet and Kjeøy. While there have been subsequent discussions and adjustments (e.g. Glørstad 2004; Jaksland 2001), the chronology used to characterise the Mesolithic of south-eastern Norway has generally followed along the lines of the framework used by Glørstad (2010:23, see Table 2.1).

In a comprehensive reassessment that draws on results from the last decades of excavations, Reitan (2022) has recently suggested a new chronological framework for the Mesolithic period in south-eastern Norway (also Reitan 2016). As his focus has mainly been on technological and typo-chronological developments, and given their recent date of publication, this framework has yet to be comprehensively evaluated in terms of correspondence with other societal developments. The presentation of major chronological trends in the sections below thus follows the traditional periodisation, as this underlies most of the cited studies. Since the papers for this thesis largely operate independently of this periodisation, which will be presented in more detail in later chapters, the chronological framework used here is mainly meant to set a heuristic and general frame of reference for the developments that are believed to have characterised the Mesolithic in the region.

Before the 1990s, the Mesolithic material from south-eastern Norway was mainly derived from stray finds (see e.g. Bjørn 1934a, 1934b; Hagen 1946), some early surveys and investigations in the mountain regions (e.g. Indrelid 1977; Odner 1965), and investigations of a handful of sites in the coastal areas (e.g. Johansen 1964; Mikkelsen 1975b, 1989; Mikkelsen et al. 1999; Østmo 1976; cf. Glørstad 2006:11–70). From around the 1990s and onwards, there has been a dramatic increase in excavations of Mesolithic sites in south-eastern Norway. This extends from smaller-scale investigations of individual sites (see Damlien et al. 2021 for a recent overview), to larger multi-year projects in the counties of Østfold (Glørstad 2004), Hedmark (Boaz 1997; Stene 2010), Vestfold and Telemark (Berg-Hansen et al. 2022; Jaksland 2014; Melvold and Persson 2014; Reitan and Persson 2014; Solheim 2017a), Vest-Agder (Ballin and Jensen 1995; Reitan and Berg-Hansen 2009), Aust-Agder (Reitan and Sundström 2018), and Akershus (Ballin 1998; Jaksland 2001; Rosenvinge et al. 2022). The material directly studied for this thesis stems from Vestfold, Telemark and Aust-Agder (Figure 2.1). This study area is located firmly within what has been considered an area of comparable material culture throughout the Mesolithic in the northern Skagerrak area, and the region falls within the administrative region of the Museum of Cultural History under the University of Oslo, which is responsible for all excavations of Stone Age sites in the region.

2.2.1 The Early Mesolithic (9300–8300 BCE)

The first human presence in Norway is recorded from around 9500–9300 BCE, which marks the start of the EM. A central discussion has concerned whether people first migrated into the area of present-day Norway from a route along the coast of western Sweden, from the north-east along the North-Norwegian coast (Bjørn 1929), or across the Norwegian trench to south-western Norway from Doggerbank (Odner 1966:135–136). The most recent evidence suggest that a crossing from Doggerbank would not have been feasible due to the distances involved at the time (Glørstad 2016; Glørstad et al. 2017). The present consensus is therefore that the earliest human dispersal into present-day Norway is likely to have originated on the coast of what is today western Sweden around 9500–9300 BCE (e.g. Bang-Andersen 2012; Bjerck 2008, 2021; Fuglestvedt 2012; Glørstad, Gundersen, et al. 2020). From here, human occupation is believed to have rapidly extended along most of the Norwegian coastline, while a north-eastern migration reached Kola and northern Norway sometime before 9000 BCE (Manninen, Damlien, et al. 2021), possibly even before 9500 BCE (Kleppe 2018). These two routes are associated with the genetically defined 'western' hunter-gatherers that migrated from the south, and 'eastern' hunter-gatherers migrating from the north (Günther et al. 2018), each identifiable also in terms of distinct material culture and associated technological traits (Manninen, Damlien, et al. 2021).

Pioneer sites in Norway and Western Sweden have traditionally been ascribed the archaeological cultures or techno-complexes Fosna and Hensbacka, respectively. Today these are seen as representing the same phenomena (e.g. Bjerck 2008:75). Fosna/Hensbacka sites are to have fairly homogeneous lithic inventories, and are held by many as having a common origin tracing back to South-Scandinavian and North-European Palaeolithic Ahrensburg groups (e.g. Bang-Andersen 2012; Bjerck 2008; Fuglestvedt 2012; Schmitt et al. 2009). The analyses of artefact inventories, the presence of high-quality South-Scandinavian flint, and the chronological support of radiocarbon dates have in sum led to the consensus on this continental connection (e.g. Bang-Andersen 2012; Fischer 1996; Fuglestvedt 2007, 2009; Glørstad 2016; Schmitt et al. 2006).

Based particularly on analyses of lithic technology (Fuglestvedt 2007, 2009, 2010), Fuglestvedt (2012:8) has even proposed that the terms Fosna/Hensbacka be abandoned altogether, in favour of Ahrensburg, as this would accentuate the continental elements that appear so defining for these pioneer sites. Although this has been met with varying degrees of enthusiasm (e.g. Åstveit 2014, with comments; Bjerck 2008:73), particularly by those emphasising the strong marine orientation of the Fosna/Hensbacka, there has also been the occasional use of variations such as 'coastal Ahrensburg' to denote the Fosna/Hensbacka (Prøsch-Danielsen and Høgestøl 1995). Following a recent analysis of lithic inventories from the transition from the Palaeolithic to the Mesolithic in Northern Europe, and comparison with Fosna/Hensbacka sites in Norway and Sweden, Berg-Hansen (2017, 2018) has emphasised nuances in the Fonsa/Hensbacka assemblages that she argues have a clearer similarity with EM Maglemose sites in Denmark. While there are elements of this technology that point back to the Ahrensburg, she argues that these societies should therefore, as with the Maglemose, be considered explicitly Mesolithic and not a northern continuation of Palaeolithic life-ways. At any rate, these discussions do go to show that there is a clear affinity between the first human population on the Scandinavian Peninsula and continental hunter-gatherer groups.

To account for the apparent pan-regional homogeneity that is to characterise the archaeological material in the earliest part of the Mesolithic, a central question is by what process Norway and western Sweden were initially colonised (e.g. Bang-Andersen 2012; Berg-Hansen 2017; Bjerck 2009; Blankholm 2008; Fuglestvedt 2012; Glørstad 2016; Schmitt et al. 2009). An important aspect in this regard is the fact that the coastal areas in western Norway were largely ice-free around 3000 years before the first recorded human presence in Norway (Mangerud and Svendsen 2022), and must have been rich and desirable areas in terms of resources early on (Bang-Andersen 2012; Bjerck 1994, 2009; Glørstad 2016).

Bjerck (1994; 2008:85; 2009; 2017) has explained the fact that people did not start exploiting these regions until around 9300 BC with reference to less developed marine subsistence strategies among North-European hunter-gatherer groups. The coastal location of the majority of Fosna/Hensbacka sites will undoubtedly have necessitated extensive adjustment to marine environments, including by the use of boats. Following the delay induced by this, the hunting of seal, conceptually not that different from the hunting of large terrestrial mammals, might have spurred an increased development of boating technology, while at the same time lending itself to the continued use of a continental artefact inventory (Bjerck et al. 2016; Bjerck 2009). Proficient and effective use of boats might in turn have resulted in a relatively rapid colonisation of Fosna/Hensbacka areas, possibly as fast as over a period of only 200–300 years (Bang-Andersen 2012; Bjerck 1994), providing a possible explanation for the homogeneous assemblages. These could reflect mobility of a kind not allowing for familiarisation with local resources for tool production, nor the development of distinct inventories adjusted to various geographical settings. The assemblages might therefore represent a sort of catch-all tool-kit, suitable to meet the variable demands of a 'pioneer condition' (Bjerck 2017; see also Breivik and Callanan 2016). Furthermore, both Fuglestvedt (e.g. 2009:371–372) and Berg-Hansen (e.g. 2017:232) have argued that the homogeneity in the lithic inventories could be related to closely knit social ties, which has enabled this technological conservatism. Homogeneity and continuity in lithic technology over vast expanses of Scandinavia would, in this view, be difficult to envision with a thinly spread population consisting of more isolated groups (see also Rowley-Conwy and Piper 2017).

Glørstad (2016) places more emphasis on how the process of deglaciation might have delayed human migration to present-day Norway, as opposed to the logistic challenges these areas might have represented for North-European hunter-gatherer groups. The morphology of the Oslo fjord means that although large coastal areas in Norway were ice-free in the first centuries of the Holocene, the inner most parts of the fjord would have been covered by ice further up in time. Although the timing for deglaciation of the inner parts of the fjord is not precisely dated (Mangerud and Svendsen 2022:64), this would have partly obstructed the further spread of environmental elements from the continent. The fjord itself would also have been a broader bay, making any crossing by boat a formidable, if not impossible task before the protective archipelago could be followed along at least most of the coastline. Parallel to this, isostatic uplift eventually resulted in the decline of the central coast of Western Sweden as a prime location in terms of marine resources (Schmitt et al. 2009). This was due to the closing off of straits connecting the North Sea and present-day Baltic Sea – a process that concluded around the later parts of the Preboreal (see Figure 2.2). As a result, southern foraging groups might have found it increasingly necessary and convenient to extend northwards along the coast (Glørstad 2016). Previous explanations such as that of Bjerck might therefore have overemphasised the unique challenges posed by the geographical setting of Norwegian coastal landscapes. This debate is by no means concluded, however, and authors such as Bjerck (2013, 2017) and Bang-Andersen (2013) have met many of Glørstad's suggestions with reluctance, including what they consider a downplay of the logistical demands that these coastal areas must have presented, also following the retreat of the ice.

In general, the Early Mesolithic in Norway is understood as characterised by highly mobile groups, reflected by what is typically interpreted as small, homogeneous sites located at exposed locations in the landscape (e.g. Bjerck 1994, 2008; Fuglestvedt 2012; Nærøy 2000), as well as lighter, more expedient dwelling structures in the form of tent-like structures (e.g. Åstveit 2009; Fretheim 2017:219). As there is little organic material on which to base inferences on subsistence from this period, there is little direct evidence to go on when attempting to determine what available resources made up the diet of people in Norway in the first centuries of human occupation. Given the North-European origin of the first humans in Norway, the hunting of reindeer has been suggested to be a possible driver behind the initial colonisation. However, the EM sites are predominantly found along the coast, and so there is little doubt that aquatic resources have played a central role (Bang-Andersen 2012; Bjerck 2008; Fuglestvedt 2014; Indrelid 1978; Svendsen 2018).

However, it cannot be excluded that a variety of species of terrestrial mammals, fish, fowl and flora have also been important constituents of the diet (Åstveit 2014; Fuglestvedt 2014; Mansrud and Persson 2018). While the settlement is focused on the coast, there is also a presence in the inland and mountain regions of south- and north-western Norway from a very early stage, which is believed to have been related to the hunting of reindeer (Bang-Andersen 2012; Breivik and Callanan 2016; Hagen 1963; Svendsen 2018). Persson (2018:207) argues that the contemporaneous establishment of coastal and inland sites is an indication that pioneer populations were neither specialised inland reindeer hunters nor specialised marine foragers who then later expanded their resource base (see also Åstveit 2018). Furthermore, Mansrud and Persson (2018) argue that the presence of microliths, which is to be indicative of bow-and-arrow technology, combined with the environmental backdrop of increasing temperatures, the reduced oceanic influence from the melting ice sheet, and the strengthening of the NwAC, in sum points towards a wider spectrum of resource exploitation. This as opposed to what has in the literature sometimes been cast in a dichotomous and one-sided focus on either seal or reindeer (see e.g. discussion by Åstveit 2014 with comments).

Given the lack of direct evidence for subsistence strategies, the analysis of settlement patterns and overall palaeoecological developments is typically drawn on to make general inferences regarding the question of resource exploitation. The coastal EM sites have been characterised as having a tendency to be situated on small islands (Breivik 2014; Nyland 2012), and been exposed to the sea (Bang-Andersen 2003; Breivik 2014). This is argued to reflect the importance of marine mammals, especially seal, in the EM.

As a counterpoint, there have been several exceptions demonstrated against the tendency of EM sites to be situated at exposed locations and on islands (Darmark et al. 2018), and some authors have argued that the degree of site homogeneity and differences in settlement patterns compared to later periods has been exaggerated or is not properly understood (Åstveit 2014; Glørstad 2013; Viken 2018; see also Damlien et al. 2021:79–81). Furthermore, in a recent study I found that the settlement patterns in a subregion of south-eastern Norway was fairly similar across the EM, MM and LM (Roalkvam 2020). Of the considered variables, the most important driver of settlement patterns was found to be degree of exposure, where the sites were found to be located with relatively open immediate surroundings, while at the same time being sheltered from larger stretches of open sea. However, one of the locational patterns that was not considered was the location of the sites within the wider landscape. The term exposure has been used to denote both how commanding the view would have been from the sites and how exposed the sites would have been to wind and wave-action (Svendsen 2014), but has also pertained to their location relative to deeper fjords and outermost coast (e.g. Bergsvik 2001; Bjerck 2008; Jaksland 2001; Lindblom 1984; Nyland 2012; Svendsen 2018). It has been argued that EM sites would have mainly been located on the outer coast, and that the fjords were not utilised until a later stage, which could reflect the distinction between resource bases mainly focused on marine mammals contra fish.

In recent work, Breivik (2014, 2020) has focused on diachronic variation through the EM in Norway. She argues that while the PBO was defining for the conditions for earliest human colonisation of Norway, with favourable conditions for Arctic marine mammals such as seal, the strengthening of the NwAC led to a more stable marine environment towards 8800 BCE. This change in environmental conditions could be related to what she identifies as a shift in settlement patterns and site types around the middle of the EM. While the developments in Skagerrak has seen a varied impact from Atlantic waters, and is heavily influenced by developments of the Baltic Sea, this diachronic distinction nonetheless underscores the point that treating the EM as a unified aggregative temporal unit could suppress important temporal variation within the phase – variation that is potentially better accommodated by the separation that Reitan (2022) makes between the Single-Edged point phase and the Høgnipen point phase (Table 2.1, see also Chapter 3).

2.2.2 The Middle Mesolithic (8300–6300 BCE)

While the Middle Mesolithic (MM) was defined as a separate typo-chronological phase in the 1970s, Bjerck (2008:92–98) stated as late as 2008 that the period was associated with a limited archaeological material, thus posing an analytical challenge. This is in part related to sea-level transgressions in this period along the coast of southern and western Norway. In south-eastern Norway, which has not been subject to sea-level transgression, the lack of MM material could in part be related to the fact that MM sites are located at elevations that have historically not been impacted by the expansion of infrastructure, and thus not targeted by archaeological investigations (Jaksland 2001:27). This picture has changed dramatically over the last couple of decades, and in addition to the excavation of individual sites, an expansive MM material has been investigated within the study area of this thesis in larger projects such as E18 Bommestad–Sky (Solheim and Damlien 2013), Vestfoldbaneprosjektet (Melvold and Persson 2014), E18 Tvedestrand–Arendal (Reitan and Sundström 2018), and Intercity Vestfold (Berg-Hansen et al. 2022).

Discussion pertaining to the MM have in part been concerned with whether the period has more in common with the highly mobile societies of the EM or with what was is typically seen as more sedentary or semi-sedentary LM societies (e.g. Bang-Andersen and Bjerck 2005; Berg-Hansen et al. 2022; Glørstad 2010; Mansrud 2014; Solheim and Persson 2016; see also the third paper of this thesis, Roalkvam 2022). There is a clear shift in material technology around the end of the 9th century BCE (Bergsvik and David 2015; Damlien 2016; Eymundsson et al. 2018; Mansrud and Persson 2018; Reitan 2022; Solheim et al. 2020; Sørensen et al. 2013), which coincides with a genetic mix between the populations originally migrating to the Scandinavian Peninsula from the south and those extending southwards from the north-east (Günther et al. 2018; Manninen, Damlien, et al. 2021; Skar 2022). However, several aspects of these societies are still believed to show similarities with the EM. For one, MM sites have, as with the EM sites, traditionally been seen as remnants of shorter stays (Jaksland 2001; Mansrud 2014:87). Furthermore, based on sites from northern Vestfold, Berg-Hansen et al. (2022:662) have argued that coastal settlement patterns in the start of the MM appear to be a continuation of those from the EM, characterised by a site location concentrated to the outer coast.

However, other aspects of the MM show a clearer break with the preceding EM. Bjerck (2008) notes that the MM is characterised by a degree of regionalisation in the lithic material that is not evident in the EM material. One feature of the lithic inventories is an increased use of locally occurring non-flint material, which is often held to indicate an increased familiarity and attachment to local areas (Berg 1997:109; Jaksland 2001:110). This is most clearly represented by the introduction of so-called chubby core adzes, as well as shaft-hole hatchets and mace heads (Eymundsson et al. 2018; Reitan 2022). Furthermore, recent investigations in south-eastern Norway has revealed what has been interpreted as integrated settlement systems consisting of sites with different functions, as opposed to the homogeneous sites that are to characterise the EM (Berg-Hansen et al. 2022; Solheim 2013; Solheim and Persson 2016).

While there appears to be a high diversity of dwelling structures from the MM in Norway, including some that are reminiscent of those from the EM (e.g. Granados 2023), substantial sunken dwelling-structures dated to the MM have also been identified (Berg-Hansen et al. 2022; Bjerck 2008; Fretheim 2017:220; Mjærum 2018; Solheim and Olsen 2013). The higher investment of time and resources that these dwelling structures represent has been taken by many to indicate an increased residential focus on the area in which they were built (e.g. Åstveit 2009; Berg-Hansen et al. 2022; Bjerck 2008; Fretheim et al. 2016; Solheim and Persson 2016).

Furthermore, the MM sees an increased exploitation of inland and mountain regions (Boaz 1999; Indrelid 1994; Persson 2009, 2018; Selsing 2010), and it has been suggested that a separate inland population is established in this period in south-eastern Norway (Damlien and Solheim 2018). The exploitation of red deer, reindeer and especially elk appears related to these inland sites – a practice that is suggested to be firmly established around 6500 BCE (Mjærum 2018). The comparatively low number of EM sites in the inland areas of Eastern Norway should also be seen in light of the fact that the ice sheet did not melt entirely until probably around 8000–7500 BCE (Mangerud and Svendsen 2022:65), and that environmental conditions conducive of a larger elk population with stable migratory routes was established after c. 7000 BCE (Mjærum 2018:188). However, Boaz (1999:132–133) has argued that human occupation in these inland regions followed some time after productive biotopes were already established in parts of this area, and therefore that this delay mainly reflects cultural factors rather than environmental ones.

Stable isotope data from human remains dating to the Norwegian Mesolithic is published for two sites. One individual is from the Viste cave in western Norway, dated to around 6200–6000 BCE (Schulting et al. 2016), and for between two and five individuals found at Hummervikholmen in southern Norway, dated to between c. 8200–7000 BCE (Skar et al. 2016). The δ^{15}N for these individuals are the highest measured for any Mesolithic individuals in Scandinavia, and indicate a heavy reliance on higher-trophic marine resources such as marine mammals and piscivorous fish (Schulting et al. 2016; Skar et al. 2016; Solheim 2020). However, as the isotopic evidence is limited, and isotope analysis of human remains from Huseby Klev (c. 8500–7500 BCE) and Uleberg (c. 5500 BCE) in western Sweden indicate the inclusion of terrestrial species in the diet (Lidén et al. 2004), it is not clear how representative these results are for the Mesolithic in Norway as a whole (see Solheim 2020).

Furthermore, while there are several taphonomic factors that might bias the preservation of faunal material, this material does appear to offer support for changes in the resource base from the EM to the MM. In their review of the osteological material from MM sites in western Sweden and south-eastern Norway, Mansrud and Persson (2018) find support for a comparatively broad-spectrum resource-base in the MM that includes the exploitation of fish, birds and both terrestrial and marine mammals. While fish and marine mammals appear to have constituted the main components of the diet, terrestrial species could have constituted parts of the diet while also providing raw-materials for the production of clothes and tools.

While a wide exploitation and specialisation towards fishing has traditionally been argued to be a characteristic of later Mesolithic phases and be related to an increase in sedentism, finds of fish hooks and assemblages associated with a dominating abundance of fish remains has pushed back this date to the MM (e.g. Bergsvik and David 2015; Boethius 2018a; Boethius et al. 2020; Mjærum and Mansrud 2020; Ritchie et al. 2016). Whether indications of extensive exploitation of fish can be pushed even further back in time remains to be determined, but given the taphonomic bias and challenges with archaeological recovery that impacts the detection of fish bone (e.g. Boethius 2018a, 2018b), it is not unthinkable that the antiquity of extensive fishing in the Norwegian Mesolithic remains underestimated (Bergsvik and Ritchie 2020:240).

Unlike the genetic changes and changes in lithic technology that are believed to be more abrupt around the transition to the MM, Berg-Hansen et al. (2022) argue that other aspects, such as the transition to different settlement patterns and an increase in the use of non-flint material, is a more gradual process. This highlights the fact that while it appears relatively established that migration events resulted in pervasive changes to the Mesolithic societies in south-eastern Norway around the transition to the MM, a lot remains to be understood concerning the process and timing by which this happened, and the consequences it had at the societal level – thus highlighting the complexities that are associated with migratory events (e.g. Anthony 2023). Moves to challenge the established chronological framework, such as that proposed by Reitan (2016, 2022), can potentially help in an endeavour to untangle these developments, and accepting that different societal processes might operate and be recognisable at differing temporal and spatial scales is also imperative in this regard.

2.2.3 The Late Mesolithic (6300–3900 BCE)

The LM is in many respects seen as a period in which the societal developments towards semi-sedentism and social differentiation that several authors have argue begun in the the MM, intensify and become firmly established (e.g. Bjerck 2008:104–105; Fuglestvedt 2018:16–17).

The period sees an increase in the use of local non-flint material, especially represented by the Nøstvet core adze, and a few sites interpreted as specialised adze-production sites date from this period (Eigeland and Fossum 2014; Glørstad 2011). The western Swedish equivalent to the Nøstvet phase is denoted Lihult, and, as with preceding periods, these are now considered to represent the same phenomena (Glørstad 2011). However, in Reitan's (2016, 2022) re-evaluation of the material, he has not found indications that the typological indicators that are to be clear markers of the Nøstvet phase occur earlier than around 5600 BCE. Furthermore, and as a potential counterpoint to the gradual intensification of societal traits that are first introduced in the MM, the transition to the classic Nøstvet material record appears to represent a clear and relatively sudden typological break (Reitan 2022).

The transition to the LM phase entitled Kjeøy, occurring around 4600–4500 BCE (Table 2.1), is indicated by the re-introduction of flint projectile points, as well as a change in the production techniques of adzes and a reduction in their number (Reitan 2022). Based on changes in lithic technology (Eigeland 2015), and possible fluctuations in relative population numbers (Nielsen 2021a), it has been suggested that new people have migrated to the coastal areas of south-eastern Norway from the south in this period. The Kjeøy phase and its relation to the preceding periods must, however, be considered relatively poorly understood as there has historically been limited material available, and as the phase has not received the same amount of focused research as other Mesolithic phases (Damlien et al. 2021:100).

Taken as a whole, the LM sites in Eastern Norway are argued be characterised by an increased variation in size, artefact inventories and topographical location (Lindblom 1984), which includes several sites that are interpreted as the result of repeated stays of a longer duration (Glørstad 2010). Furthermore, the period has also been argued to be characterised by an increase in social differentiation and the establishment of territories within the region (Fuglestvedt 2008, 2018; Glørstad 2010:160–165; Jaksland 2001:119–210; see also Boethius et al. 2020).

There is evidence for increased use of inland and mountain regions in the LM (e.g. Damlien et al. 2021), and the most substantial Mesolithic dwelling structures in south-eastern Norway are found in inland regions and date to this period. These are represented by semi-subterranean housepits, associated with large accumulation of fire-cracked rocks, which in sum is taken to indicate their use in the winter season (e.g. Boaz 1999:143–146).

However, also inland utilisation appears to demonstrate fluctuations that are possibly better accommodated by Reitan's (2022) alternative chronology. Based on excavations in Rødsmoen and Dokkfløy in the inland region of south-eastern Norway, Boaz (1999) suggested that a significant peak in inland activity was reached around 6000 BCE. This is followed by a considerable drop until a second peak occurs around the onset of the Neolithic, c. 4000 BCE. This development has largely been confirmed by Selsing (2010) in a comprehensive evaluation of the data available from the mountain regions of Southern Norway, and by Persson (2018) who also included sites from the more recent Gråfjell project in Hedmark (Stene 2010). These developments thus roughly correspond to an increased inland activity in Reitan's Pecked Adze Phase, followed by a drop and lower inland activity in the Nøstvet Adze phase and Transverse Arrowhead Phase. Although this fluctuation has been given several possible explanations (as discussed by Persson 2018), Boaz (1999) related it to the establishment of more clearly separated inland and coastal settlement, where a specialised Nøstvet adaptation in the coastal areas led to a cessation of seasonal movement to the interior.

Increased territoriality has in part also been related to the not previously mentioned material category of rock art. Rock art is present from the EM in northern Norway (e.g. Gjerde 2021), but the LM marks the onset of what Fuglestvedt (2018:17) terms 'the great wave' of rock art in Norway. Furthermore, in Eastern Norway, rock art does not appear to be introduced before c. 5700 BCE (Fuglestvedt 2018:42–46; Glørstad 2010:216–233), thus roughly corresponding to the onset of Reitan's Nøstvet Adze Phase. While there are some challenges associated with the dating of rock art, this dramatic increase cannot reasonably be ascribed taphonomic effects or investigatory biases, and can therefore be taken to represent a clear indication of cultural changes with the LM. This increase in rock art is often interpreted as an increase in ritual behaviour of a kind that establishes a firm attachment to their location in the landscape, in turn thus supporting the notion of an increased degree of territoriality (e.g. Glørstad 2002:32–33).

Although mobility is argued to generally decrease and territoriality increase with the LM, this is qualified by Glørstad (2010:97) who states that while expedient mobility in surrounding landscape appears to be reduced, better terms might be that mobility became more structured and regulated, as longer-distance contact- and mobility-networks appear to have been established at the same time. This is reflected by the occurrence of flint in inland regions where this would not have been available naturally. The same notion is also reflected in the work of Fuglestvedt (2018), who on the grounds of shared motifs in rock art from eastern, north-western and northern Norway has argued the case for wide-ranging contact-networks in the LM.

Related to the increased evidence for ritual behaviour is also the only secure grave-find from the Mesolithic in south-eastern Norway, represented by an inhumation grave containing a single individual from the site Brunstad in Vestfold (Reitan et al. 2019; Schülke et al. 2019). Due to the poor preservation of the bones, neither ^{14}C-dating nor stable isotope analysis of the bones was successful. However, contextual information and dates from relating features date the grave to c. 5900 BCE. The grave was found as part of a site complex of three sites on what would have been an island in the Mesolithic. The sites were interpreted as the result of repeated visits between c. 6400–5600 BCE.

In western Norway, Bergsvik (1995, 2001) found that large LM sites associated with the accumulation of thick organic deposits were located close to good fishing locations along straits, and in combination sees this as an indication of an increased degree of sedentism and territoriality towards the later parts of the Mesolithic (see also Bergsvik 2006:149–150, 168–171). Furthermore, zooarchaeological evidence from rock shelters appear to indicate an increased specialisation towards fishing in the LM (Ritchie et al. 2016), and Bergsvik et al. (2016) argue that a shift towards sedentism in western Norway occurs around 6100 BCE. While the same kind of sites with extensive organic deposits located along straits have not been discovered in south-eastern Norway – possibly due to investigatory and taphonomic factors – a similar development has been suggested for this region. Glørstad (2010) argued that larger LM sites appear to have been situated at locations with an especially good access to marine resources, and Lindblom (1984) linked a similar argument to the location of the LM sites in fjords and the inner archipelago. It is thus possible that practices of settlement patterns and resource exploitation, introduced with a decrease in residential mobility in the MM, is intensified through the LM.

2.2.4 The end of the Mesolithic

Around 4000 BCE, agriculture is introduced in southern Scandinavia with the Funnel Beaker Culture, with direct agricultural evidence extending as far north as Bohuslän in Western Sweden on the border to present-day Norway (e.g. Sørensen 2014). While evidence for agriculture from the Early and Middle Neolithic in south-eastern Norway is sporadic and uncertain (e.g. Solheim 2021), other dimensions of the archaeological record clearly demonstrate influence from bordering agricultural societies, represented by artefacts such as pottery, polished flint axes, as well as a few megalithic dolmens in the Oslo fjord region (e.g. Østmo 2007). The nature of this transition and the role of the potential agricultural traces have been widely discussed. In many respects the first part of the Neolithic is viewed as a continuation of Mesolithic settlement patterns and subsistence base, but the changes in material culture indicate wide-ranging contact-networks and potentially internal developments that nonetheless appear to represent a significant societal shift (discussed by e.g. Glørstad 2012; Glørstad, Solheim, et al. 2020; Nielsen et al. 2019; Nielsen 2021b; Nyland et al. 2023; Østmo 1988; Prescott 1996, 2020; Solheim 2021). Reitan (2022) suggests that from a typological point of view, the transition to the Neolithic should be defined by the introduction of pottery and polished axes, rather than the currently weak indications of agricultural practices, and therefore sets the end of the Mesolithic in south-eastern Norway to 3900 BCE. This therefore also means that term Neolithic, when used to denote end of the Mesolithic in a Norwegian setting, does not imply the fundamental economic and societal changes with a wide adoption of agriculture that the term typically connotates in other parts of the world (called an 'artifactually defined Neolithic' by Rowley-Conwy 1993:350; recently discussed by Nyland et al. 2023).

2.3 Chapter summary

The above presentation has outlined the general environmental setting and overarching cultural developments that are believed to have characterised the Mesolithic in south-eastern Norway. The larger scale developments are of main interest to this thesis, where the main dimensions that have been deemed of central importance is the economic basis of these societies, associated land-use and settlement patterns, and demographic factors such as population size and migratory events. The next chapter will outline a more explicit analytical framework for how these dimensions can be understood theoretically and approached empirically, and especially how they can potentially be reflected in archaeological data such as site frequency, lithic assemblages and the position of the sites in the landscape.

Chapter 3

Analytical background

The last chapter outlined the environmental and archaeological background for the thesis. This chapter presents underlying analytical concepts that have motivated the research questions asked and the methods employed in the undertaken studies. The first part of the chapter outlines some issues that are fundamental to archaeology in general, pertaining to dimensions such as the quality and resolution of the empirical data, chronological frameworks and cultural taxonomies, and presents some methodological and conceptual ways in which these can be contended with. The last part of the chapter moves on to consider dimensions and characteristics of hunter-gatherer societies that are often considered to be of central importance for understanding the variation that has existed among these societies. The section on hunter-gatherers thus pertains more directly to what cultural historical dimensions the thesis attempts to elucidate.

3.1 The quality of the archaeological record

Underdetermination and equifinality are two related concepts that concern the degree to which empirical evidence can be drawn on to adjudicate between competing explanations. Equifinality pertains to the case where different processes have the same empirical result, while underdetermination pertains to the case where the available empirical evidence can be the result of different processes (e.g. Okasha 2016:66–70; Perreault 2019:1–2; Psillos 1999:162–182). The degree to which this occurs therefore impacts the hope we have of ever choosing between competing explanations, and is especially pertinent for archaeology as we deal with a fragmented empirical record fraught with various systematic and un-systematic biases that impact the quality of our data, in turn leading to the underdetermination of potential explanations.

Due to underdetermination, the quality of the data available to us is consequently fundamental for knowing what questions we can and cannot hope to answer about the past (see Perreault 2019). Lower quality data will lead to averaging and smoothing, where for example a reduced temporal resolution can lead to chronological smearing that hides smaller scale oscillations and variability (Bailey 2007; Daems et al. 2023; Perreault 2018; Stern 1994). The same principle extends to the spatial scale, where a lower empirical coverage means that answers to questions pertaining to processes operating at the scale of individuals, sites or smaller regions might not be empirically tractable, and a larger view might be necessary to bring into view a process of interest, thus determining what processes we can hope to unveil. Furthermore, this issue also pertains to what Perreault (2019) terms the dimensionality of the data, that is, the features that can and have been recorded for a set of observations – for example stable isotope characteristics of human remains. Loss or otherwise reduced dimensionality can here result in a reduction of variability and richness, impacting for example the perceived characteristics of artefact assemblages.

Furthermore, loss and mixing can sometimes be more subtle effects than complete absence of data, which can potentially be more easily recognised. Moreover, effects such as loss, mixing of past events and analytical lumping will most likely not impact the quality of the data in a uniform way. Taphonomic loss is likely to be more severe the further back in time one moves (Surovell et al. 2009) and follows from geographically contingent environmental impact on preservation. Analytical biases following for example from disciplinary interests or what geographical areas have been subjected to archaeological investigation will also skew our impression of the past (Binford 1964). Mapping the spatial and temporal quality of the archaeological record is thus critical for knowing what past processes we would be able to discern, and by extension what kind of archaeology we can hope to do. For these reasons, a central aim of this thesis is to contribute to mapping the data available from the coastal Mesolithic of south-eastern Norway.

3.1.1 Digital and computational archaeology

Given the large amounts of data that have been and continue to be generated by Norwegian Mesolithic archaeology, contending with this data at even the most basic level necessitates the use and development of computational methods designed to handle this, in the words of Bevan (2015), 'data deluge'. Furthermore, most of the data generated by archaeology today is to varying degrees digital in nature, legacy data is increasingly being digitised, and digital tools are used at all levels of archaeological practice. Therefore, digital and computational methods are fundamental and intrinsic to modern archaeology, irrespective of the scale we are operating on. As Morgan and Eve (2012:534) have stated: 'we are all, whether we like it or not, digital archaeologists'.

Given this dependency on computational and digital methods, it has been argued that it is not enough for archaeologists to passively employ these technologies or to critically assess their development from afar. Archaeologists have to become active, informed and reflective participants in the development of new technologies, and in the assessment and creative application of those that already exist (Llobera 2011). As the philosopher of technology Ihde (2004) has argued, it is necessary to some degree to 'go native' (cited by Huggett 2015:88). All four papers of this thesis can be said to contribute to this through the exploration, development and open dissemination of methods and technologies for the purposes of handling data and casting this as evidence for understanding the Mesolithic of south-eastern Norway.

There can be merit to an exploratory accumulation and systematisation of the available data in its own right, both to get an overview of the processes we can hope to explain, and as it can reveal patterns in archaeological investigation and categorisation as well as help identify, and potentially average out erroneous data points or idiosyncratic and random variation (see e.g. Cooper and Green 2016; Hamilton and Tallavaara 2022). However, more data will not by itself offer any meaningful insight. Discussing this in the context of so-called 'big data' in archaeology, Huggett (2020) states that 'digital data not only offer possibilities but may also constrain actions, they limit as well as enable, and this may not always be recognized in the thrill of the revolutionary discourses surrounding Big Data and the lack of a proper data gaze.' While seeing data as given, free of influence from our preconceptions is a well-known fallacy and a long-held criticism in archaeology, several authors have expressed concerns with the degree to which developments in digital technology may lead to an over-enthusiasm that neglects the messy, fragmentary and complex nature of archaeological data, and that this can lead to fetishisation of digital data following from its availability, tractability and often elegant-seeming results (see e.g. Hacıgüzeller 2012; Huggett 2020; Solli 2007).

While large amounts of data do not offer a way to side-step the fundamental issues with archaeological evidence, there is nonetheless decidedly value to evaluating data at multiple scales. Not only can this reveal patterns and processes that operate at some scales and not at others, but different scales of perspective can also feed back to each other and reveal biases or inconsistencies. Furthermore, by drawing on for example Kuhn (1970) and the later work of Galison (1997), several authors have argued that the development and employment of digital and computational tools by themselves impact the fundamental practice of doing archaeology (Grosman 2016; Schmidt and Marwick 2020) – an effect that extends beyond the scale these methods can operate on. Active, informed participation and sharing of digital and computational tools is therefore likely to advance archaeology by leading to a situation where 'familiar objects are seen in a different light and are joined by unfamiliar ones as well' (Kuhn 1970:111).

This promise is of course also dependent on the context and ways in which data has been recorded and been made available (Cooper and Green 2016; Huggett 2014). A central issue with digital data is therefore to avoid naive empiricisms and to offer transparency with regard to its creation, manipulation, handling and finally with how it is cast as evidence. This will allow ourselves and others to assess how these steps might influence the arguments that are made. The ways in which these issues are attempted to be tackled in the context of this thesis will be laid out in more detail in Chapter 4.

3.2 Chronology, cultural taxonomy and modifiable analytical units

The study area of this thesis, situated within south-eastern Norway, is for the most part believed to have followed a similar trajectory in terms of overall cultural-historical developments and expressions of material culture through the Mesolithic. At least within the analytical detection limit that has characterised the field thus far. What has been of greater concern is the temporal transition between the occurrence of cultural taxonomic elements within the region. In Norwegian Mesolithic research more widely, however, the question of both regional variation in material culture and its timing has led to discussions of whether a concept known as 'chronozones' has any merit as a framework for systematising the archaeological material. This is a concept that has remained marginal in archaeology as a whole, but is used by several practitioners in Norwegian Mesolithic archaeology (e.g. Bjerck 2008; Breivik et al. 2018; Fretheim 2017; Fuglestvedt 2018; Nyland 2016; Skar and Breivik 2018), and is related to fundamental issues faced within archaeology.

The concept originates in a paper by Bjerck (1986), in which he attempts to tackle the distinction between the archaeologically defined cultures of Fosna and Nøstvet in the context of Western Norway. Instead of an ever-continued nuancing of these terms as more variation and idiosyncrasies are encountered in the archaeological record, Bjerck (1986:117–119) instead suggests a division of the Mesolithic period into a series of time intervals denoted chronozones, originally at a resolution of 500 years, which he argues could facilitate a pan-Scandinavian framework for approaching the Mesolithic (Bjerck 2008:72–73). The concept of chronozones is taken from the geosciences, where the term is used to denote stratigraphic layers that formed over the same specific time-span on a regional or world-wide scale, known from geochronological units such as for example the Preboreal, Boreal and Atlantic time intervals (e.g. Salvardor 1994:83–85). Bjerck's motivation for adapting this to archaeology is to form a framework that is neutral with respect to cultural variation across space and time. He argues that traditional archaeological units of analysis, typically denoted by terms such as cultures or techno-complexes that are discretely delineated in time and space, has led to an artificial partitioning of the archaeological material that is less open to gradual temporal change and spatial variation – an issue that has been contended with by many archaeologists through the years (e.g. Butzer 1982:279–320; Childe 1956:121–125; Clark 2009; Reynolds and Riede 2019; Roberts and Vander Linden 2011; Smith 1992). Bjerck argues that the use of neutral 500-year time intervals will reduce the degree to which analyses will overemphasise homogeneity within, and exaggerate differences between such analytical units. To further illustrate the issues Bjerck (1986) attempted to tackle, it is useful with a detour via the concepts of the Modifiable Areal Unit Problem (MAUP), as taken from the field of geography (e.g. Harris 2006), and its recently coined temporal equivalent, the Modifiable Temporal Unit Problem (MTUP, Bevan and Crema 2021).

3.2.1 The MAUP and MTUP

The scale problem, as it is often called, is central to geographical research. This follows from the scale that is chosen in the necessary generalisation of continuous phenomena, the dependency of this generalisation on the density of sampling points, and the variable spatial scales that different phenomena operate across (Harvey 1968). Some central implications Haggett (1970) identifies in relation to this is the *scale coverage problem*; related to the choice of variable sampling designs and intensities for undertaken studies, the *scale linkage problem*; the problem of comparing results captured at one spatial scale with those captured at another, and the *scale standardisation problem*; the issue of how data that have been captured on varying spatial scales are adjusted to a common scale (Harris 2006:46). Extending on the last problem, Haggett (1970:177–179) shows how adjusting the boundaries used to delineate the originally retrieved data can have substantial consequences for any basic comparisons of the occurrence of phenomena within these units, which is the issue that underlies the MAUP.

The MAUP is defined by Heywood et al. (2002:8) as ‘a problem arising from the imposition of artificial units of spatial reporting on continuous geographical phenomenon resulting in the generation of artificial spatial patterns’ and is an issue that underlies most if not all analyses that draw on areal data (Harris 2006:48). A common example from archaeology is the areal unit of the site, the delineation of which typically follows some notion of concentration of artefacts. However, the density of artefacts over a landscape can be conceived of as a continuous phenomenon, and so its definition will always be modifiable and subject to choice, whether it follows from some kind of statistical procedure or a more intuitive definition (e.g. Dunnell and Dancey 1983; Hodder and Orton 1976:17–19; Thomas

1975). The same problem extends to the smaller scale, such as with the definition of site features based on the concentration of charcoal, and up in scale, such as to the definition of archaeological cultural areas. How these units are defined will impact the most basic comparison between them. Given the arbitrariness and potential variation that might exists in the aggregation procedures underlying our areal units, it is therefore always a danger that discovered patterns could simply be artefacts of the aggregation technique.

These issues can also be extended to the temporal dimension, which Bevan and Crema (2021) have recently demonstrated in the context of archaeology by illustrating how periodisation involving lumping and splitting of phenomena within disjoint time intervals have analytical consequences that remain under-appreciated within the discipline (see also Crema 2015). First, employing strict cut-offs between temporal units – units that often also vary in their duration – has major implications for comparison between these units, and can, as Bjerck (2008:73) also notes, lead to an artificial and inadvertent overemphasis of the transition between these. Basic operations such as comparing counts will be biased by variable duration of these units, and the position of breaks between them can be highly influential to the appearance of the frequency distribution of events over time.

Building on Crema and Kobayashi (2020), Bevan and Crema (2021) further define three types of uncertainty associated with this archaeological practice. The first is *phase-assignment uncertainty* – how certain can we be that a given phenomenon can be ascribed to a given phase. The degree to which this varies between different material categories means that it can be difficult to compare their frequency across archaeological phases. As was found in the third paper for this thesis (Roalkvam 2022), the occurrence of formal tool types at the Mesolithic sites in the study appears to be greater further back in time. This as opposed to younger sites, which are to a larger extent dominated by generic debitage that can be more difficult to assign to a specific phase. This can have implications for how many sites are ascribed earlier periods, and, by extension, could impact a comparison between phases. The second pertains to the *within-phase uncertainty*, the degree to which the occurrence of various phenomena have an equal likelihood of occurrence throughout an archaeological phase. For example, in typological discussions for the Norwegian Mesolithic, the occurrence of different artefacts types is in practice typically treated as having a uniform frequency of occurrence within a given time-span. The final dimensions Bevan and Crema (2021) highlight is the *phase boundary uncertainty*, which pertains to the start and end points of the archaeological phases themselves. As these are typically defined by a complex interplay of multiple cultural phenomena, they are seldom meant to operate on the scale of individual years but will in practice often be operationalised as such.

3.2.2 Archaeological chronozones

While possible methodological ways around these issues are presented in the works cited above, neither the MAUP nor the MTUP have any clear solutions, and the magnitude of their impact will depend on the given research question and accompanying analytical scale. However, their formulations arguably form a better frame for understanding these issues than the concept of chronozones. I argue here that chronozones can instead obfuscate the distinction between the temporal and the spatial scale, and that of culturally taxonomic artefact classification (see e.g. Dunnell 1971; O'Brien and Lyman 2002; Reynolds and Riede 2019; Riede et al. 2022). Bjerck (1987) states that typology obviously has its place as a culturally responsive framework for classifying artefact variation over time and space. Here I understand typology to be meant in a wide sense, pertaining both to the act and result of classifying artefacts, and its potential role as a dating method (see references above and e.g. Berg 2021:59–65; Gräslund 1987; Sørensen 2015, for discussions concerning the typology term). By ignoring this cultural dimension, chronozones, on the other hand, are supposed to facilitate comparisons across taxonomically inferred boundaries in space and time.

In her comment to Bjerck's paper, Skar (1987:35) notes that geological chronozones couple pan-regional stratigraphic layers with the calendar scale, but that there are no equivalent pan-regional archaeological phenomena that equally consistently correspond to a section of the calendar scale. As Bjerck (1987:40) further underscores in his response, archaeological chronozones are therefore not, unlike typological frameworks, meant to be culturally responsive, but are to represent a neutral temporal scale, typically instantiated as 500-year intervals. However, as Østmo (1987) and Mikkelsen (1987) note in their comments to Bjerck's original paper, this purpose is already fulfilled by the calendar. If the stratigraphic information related to a specific time interval is removed from the geological chronozone, only 'chrono' remains. Similarly, if the archaeological chronozone is not meant to hold any culturally responsive component, only the time-scale remains.

As a culturally independent scale, the calendar scale will always be preferable to the that of chronozones. Not only because it is firmly established, but also because it already allows for more variation in the temporal resolution associated with different phenomena to be systematised, and allows for their duration and uncertainty of occurrence to span a wider range of aggregative time-units (cf. Reitan 2022:187). The ability to shift and readjust the temporal resolution depending on the phenomena one is attempting to align and contrast is important as 'different timescales bring into focus different sorts of processes, requiring different concepts and different sorts of explanatory variables' (Bailey 1987:7; 2007).

In replying to this critique, Bjerck (1987:40) states that questioning the need of chronozones when we already have the calendar is like asking 'Do we need the term “month” when we have numbered days?’. This would seem to imply that chronozones, like the month, is to be of a predefined duration, at least within any individual study, and that variable duration and temporal uncertainty of different phenomena to be analysed must be collapsed into these aggregative units. Another issue is also if the terminology used with chronozones is better than simply stating what time intervals we are dealing with. For example, Bjerck (2008) uses the term Middle Mesolithic (MM) to denote the three chronozones MM1, 8000–7500 BCE; MM2, 7500–7000 BCE; and MM3, 7000–6500 BCE. A reader coming across ‘MM3’ instead of ‘7000–6500 BCE’, or some other more neutral name, therefore has to keep in mind that this simply refers to this specific time interval. The term Middle Mesolithic should be entirely disregarded, as it is in this use meant to be devoid of any cultural meaning.

One could perhaps change terminology to something that doesn’t have as many cultural and research historical connotations as the Middle Mesolithic, but it strikes me as altogether unnecessary to do this via the chronozone, as this is simply solved by establishing a reference frame only using the calendar scale in the first place. If one wants to use a time-scale of 500-year intervals it would in my mind be better to simply define this independently of the now inflated discussion of chronozones, not least because I believe the discussions of the concept demonstrates that its use can lead to unnecessary confusion – if not for practitioners, then likely for readers.

In their comments to the original paper by Bjerck (1986), Østmo (1987) and Mikkelsen (1987) deem chronozones an unnecessary and complicating concept. Commenting on these critiques, Nyland (2016:53–56) states that both Østmo and Mikkelsen make their comments considering typological frameworks for Mesolithic south-eastern Norway, but that neither address the issue of the geographical coverage that these have. However, this is first and foremost an empirical issue rather than something to be solved by new terminology, and clearly not by the chronozone, which is a concept meant to be culturally unresponsive.

Drawing on an example given by Nyland (2016:55); if the question is if central Norway falls within the same cultural sphere as south-eastern Norway, understood to be determined by comparable material culture, then this is dependent on two dimensions, assuming the problem of the initial delineation of these two regions has been resolved. The first is an evaluation of the degree to which characteristics of archaeological material in the two regions is considered to be similar, according some criteria. The second pertains to the timing of the occurrence of this material. To establish this necessarily demands temporal data that is independent of the typological framework itself, or possibly by reference to some principle of seriation with the uncertainty that this entails (e.g. Dunnell 1970). If a set of artefact types occurs in both central Norway and south-eastern Norway, this could lead one to suggest that a similar kind of cultural expression is common to the two regions. If independent temporal data associated with this material, such as radiocarbon dates, additionally indicates that there is a temporal synchroneity between their occurrence, then this would lead one to conclude that this cultural expression appears to occur simultaneously – within some level of temporal certainty. Depending on the magnitude of artefactual and temporal evidence for this coincidence, this could then lead one to apply this typological framework as a dating method in the case that one excavates a site in either region and discovers material of the type in question. A continuous adjustment and evaluation of the reliability of the identified cultural affinity and the derived typological dating frame will of course be necessary, but it will have to be founded on material culture and the position of their occurrence on the calendar scale. This also pertains to the co-occurrence of various archaeological evidence and their wider cultural implications, for example whether or not some artefact type tends to be associated with agricultural activity. If either region lacks artefactual or temporal data, then either the nature or the timing of cultural affinity cannot be resolved. The concept of chronozones cannot overcome these issues, and, I think, is more likely to confuse them.

I therefore agree with Østmo (1987) and Mikkelsen (1987) in that the concept of chronozones represents an unnecessary complication. Although some of these complications follow from misunderstandings of the original proposition (as pointed out by Bjerck 1987:40; Nyland 2016:55), this only underscores that the concept sometimes leads to the muddling of several spatial, temporal and culturally taxonomic issues. These are therefore arguably best handled by reference to already well-established terminology, and by the use of modern methods that allows for the formal definition and handling of fuzzy and uncertain categorisation in the aggregation of data, both on the scale of material culture, time and space (e.g. Bayliss et al. 2007; Bevan and Crema 2021; Crema 2012; Fusco and Runz 2020; Leplongeon et al. 2020; Matzig et al. 2021; Riede et al. 2019; Shennan et al. 2015).

The misunderstandings and the amount of ink now spent discussing chronozones also means that invoking archaeological chronozones carries with it the necessity to clarify how one intends to use it, which can be circumvented by avoiding the term altogether. Furthermore, as a term suggested for use in Pan-Scandinavian Mesolithic research, I believe this idiosyncratic terminology will also unnecessarily divorce the field from discussions of the same issues within archaeology more widely, while also making the field less accessible to outsiders, more difficult to couple with adjacent disciplines, and possibly lead to confusion with the geological chronozone. It is therefore unclear what the concept now provides beyond what well-established archaeological and colloquial terminology already covers, perhaps apart from making us aware of these universal archaeological issues.

3.2.3 Radiometric and archaeological dating methods

Rather than being based on predefined discrete time intervals beyond the calendar scale, the analyses undertaken in the papers for this thesis largely rely on absolute dates from radiocarbon- and shoreline dating. These two methods can be denoted radiometric and archaeological dating methods, where the first category is based on a process of radioactive decay and the second is based on some regularity in human behaviour leading to predictable variation over time. In the case of shoreline dating, this follows from the proclivity of people to have continuously settled close to the shoreline throughout the Norwegian Mesolithic, where the coupling of this with the calendar scale follows from the timing of shifts in the relative sea-level. However, a note should also be made on the fact that radiometric dating is never purely based on a steady process of radioactive decay. Apart from interpretations to do with the calibration, reliability and sampling context of a radiometric date, this also has to be seen in light of other chronological information and the wider archaeological context (Wylie 2017). As with the process of shoreline displacement, the cessation of radiocarbon uptake in an organism also requires an interpretative step to be meaningfully associated with a cultural event of archaeological interest.

It is important to underscore that given the scarcity of radiocarbon dates, and the relatively low resolution of shoreline dates, typological frameworks responsive to temporal variation in material culture can most decidedly offer valuable chronological insights, even though this is not directly integrated in the studies undertaken for this thesis. Furthermore, while the analyses are done here using dating methods that largely operate irrespective of archaeological periodisation, the results are frequently narratively and informally associated with general cultural developments believed to characterise the Mesolithic of south-eastern Norway, as roughly outlined in Chapter 2. This is predominately done in an approximate manner with reference to what are best viewed as temporally and spatially fuzzy frameworks and is based on the underlying logic that frequent co-occurrence of a range of material expressions in time and space, as suggested by others, reflects some level of meaningful cultural cohesion. This also means that the term culture is used in a loose archaeological sense and is not presumed to equate to a people or a unified unit in terms of language, genetics, or social structures (see e.g. Roberts and Vander Linden 2011 for thorough discussions of the culture term as used in archaeology; and e.g. Riede et al. 2019 for perspectives that can be taken to challenge the rather simplified view taken here). While it appears reasonable to assume that such cohesion has largely resulted from the same cultural factors within the geographically limited area of south-eastern Norway through the Mesolithic, it is also worth noting that empirical correspondence can be driven by other factors. This includes cases where people have arrived at the same technology fulfilling the same purpose in disjoint regions of time and space, known as cultural convergence (e.g Mesoudi 2011:36–37), as well as cases where the same material expression has occurred across a range of different cultural and environmental settings to fulfil different purposes (as has been argued to be the case with slotted bone tool technology in Northern Europe, Manninen, Asheichyk, et al. 2021) – effectively an example of equifinality.

Finally, it is worth commenting on the concept of non-linear time and temporality as it has been approached within archaeology and the humanities more widely. In an influential paper, Ingold (1993) makes the distinction between chronology, history and temporality. Chronology is here defined as a sequence of regular time intervals in which events have occurred. History is defined as a series of events that can be aligned relative to each other by their occurrence within chronological intervals. These are thus sterile and homogeneous sequences, largely detached from a social reality. Temporality, on the other hand, pertains to how people perceive the flow of time and their own position within it, relative to both past and future. However, as Bayliss et al. (2007) point out, it is hard to see how the nature of temporality and the subjective and societal experience of time can be investigated without first establishing the sequence and duration of events on the calendar scale. To repeat Vandkilde (2007:22) as quoted in the introductory chapter: 'Chronology is the backbone of social interpretation.' (see also e.g. Holdaway and Wandsnider 2008). Focus is in this thesis therefore directed towards chronology and history (in Ingold's understanding) rather than temporality, as there are fundamental questions pertaining to the chronology of the Norwegian Mesolithic that remain unanswered. Improving our tools for establishing the chronology of events and its associated uncertainty can lay a critical foundation for future investigations of Mesolithic temporality and other non-linear conceptions of time (see e.g. Lucas 2021; Nielsen et al. 2021).

3.3 Hunter-gatherers

The concept of hunter-gatherers here functions as a foundational heuristic model from which to derive empirical avenues to be explored, and to propose possible causal drivers behind any observed patterns (cf. Warren 2022:29). Hunter-gatherers or foragers are useful but fuzzy and not unproblematic synonyms that are typically, but not exclusively, used to denote societies that have a diet based on non-agricultural produce (Kelly 2013). In the introduction to the seminal book *The Lifeways of Hunter-Gatherers: The Foraging Spectrum*, Kelly (2013:4) states that he aims at providing his readers with 'some knowledge of the variation that exist among foragers and some idea of what accounts for it'. Thus, while comprehensive in scope, Kelly (2013) is also very explicit in the limitations of his review and states that while the hunter-gatherer term can be a useful heuristic and analytical unit for human societies, it carries no explanatory weight by itself (Kelly 2013:22). The societal variation among more recent hunter-gatherer societies is immense, and as foraging has constituted the predominant life-way for humanity for 99% of its existence, the variation that can be expected among past hunter-gatherer societies is comparatively vast (e.g. Cummings 2013:33; Singh and Glowacki 2022).

With the *Man the Hunter* conference in 1966, the so-called nomadic or generalised forager model was established, in which hunter-gatherer societies was seen as small and nomadic, characterised by being egalitarian, non-territorial, non-storing and low-violence (Lee and DeVore 1968). As a response to the oversimplifying generalised foraging model, several authors pointed to examples of hunter-gatherers that deviated significantly from this model. As a consequence, several interrelated concepts were introduced as means with which to understand these deviations (e.g. Testart 1982; Woodburn 1982; see Grier et al. 2006; Kelly 2013:241–268; Lane 2014), of which forager complexity has been especially influential to archaeology (Price and Brown 1985a). In this understanding, societal complexity among foragers can include reduced residential mobility, increased population size and density, economic intensification, specialisation, and storage of resources, technological ratcheting involving increased number of artefact components and production steps, control of resources and territories, increased inter-group trade and conflict, elaboration of ceremonies and ritual behaviour, and increased social inequality with hierarchical differentiation in decision-making power (e.g. Arnold 1996; Cummings 2013:55–74; Jeffrey and Lahr 2020; Kelly 2013:241–242; Price and Brown 1985a; Zvelebil 1998).

It is, however, important to note that complexity and simplicity are not value judgements concerning what constitutes a 'better' or 'worse' kind of societal organisation, nor does it entail that simple (sometimes termed generalised) foraging societies are easier to understand than those viewed as more complex. Furthermore, the distinction between simple and complex foragers should not be understood as a discrete dichotomy. The different components of what is often associated with degree of complexity is best conceived of not as a check-list, but rather as a complex web of interrelated societal variables that are merely collapsed under the complexity term. Different components of this concept will be variably relevant in any given context (e.g. Cummings 2013) and these components can be variably related to societal complexity as conditions, consequences and causes for its emergence, permanence or lack thereof (Arnold 1996; Price and Brown 1985b). Following from issues such as those listed above, some authors have deemed the complexity term inappropriate (e.g. Kelly 2013:242; Warren 2005). However, I believe it can still inform some, but certainly not all features of hunter-gatherer societies that are of interest to elucidate, as long as care is taken to avoid a search for complexity in itself – which can lead one to force the empirical record to accord with some idealised expectation of what characterises complex hunter-gatherers. Rather than searching for complexity, a better goal is to identify how and in what ways a society is more or less characterised by explicit dimensions of forager complexity (see Warren 2005:75), and realise that employing this heuristic model reduces the variation we can hope to discern to the idealising confines of the model (Cummings 2013:74).

With increased concern for the diversities that exist among hunter-gatherers, researchers have, at least from the 1980s, increasingly focused on the immense variation that has been demonstrated and can be expected among both extant and past hunter-gatherers (e.g. Arnold 1996; Arnold et al. 2016; Kelly 2013; Lewin 1988; Price and Brown 1985b; Singh and Glowacki 2022). As a consequence, this thesis attempts to balance some insights from hunter-gatherer studies more widely, with an open and exploratory perspective. While preconceptions of hunter-gatherer societies necessarily dictates some of the analytical avenues taken and influence the type of questions that are asked, the aim is to map variation in the dimensions of interest and have idiosyncrasies of the archaeological record from coastal south-eastern Norway dictate the conclusions that are reached.

A further underlying issue with employing hunter-gatherers as a heuristic category with which to approach the material, are ways in which the history of research into such societies might inadvertently dictate how the data is treated. For example, a unilineal socio-evolutionary perspective was a fundamental influence at the inception of the research into hunter-gatherers (e.g. Kelly 2013:4–7). While such views are deemed a grossly inappropriate reference frame today, it can be difficult to fully grasp and account for ways in which this influences the fundamental categories we operate with, however divorced they may now appear. Related concerns have also been voiced in Norwegian Mesolithic research, where for example Åstveit (2014) is vary that a view of EM societies as highly mobile and LM societies as more sedentary might, at least in part, follow from an implicit view of prehistory as characterised by a continuous trajectory towards increased societal complexity. This implicit view might have forced us to cast the material traces available to us to meet these expectations.

Calls for more directed attempts at unveiling how such research-historical conditions might influence how we conduct Mesolithic research have recently been voiced (Elliott et al. 2022; Elliott and Warren 2023). While it is beyond the scope of this thesis to contribute much in the way of bringing these influences and their consequences to light, the next chapter will outline a framework that is employed in an attempt to clarify the evidential logic that underlies the undertaken studies. Hopefully, this can contribute to making evident where such biases might have influenced any analytical choices and the conclusions that are reached.

3.3.1 Hunter-fisher-gatherers

One implication of the defining economic characteristic of hunter-gatherers appears to be a case where environmental variation represents a considerable factor in structuring cultural variation. Environmental variability has been frequently shown to impact central aspects of forager societies, such as economy, population dynamics and mobility patterns, which in turn can be interrelated with virtually all dimensions of these societies (e.g. Binford 1990; Bird and Codding 2008; Hoebe et al. 2023; Jørgensen 2020a; Kelly 2013; Morgan 2009; Ordonez and Riede 2022).

However, while it appears to be the case that variables such as temperature and precipitation dictate general variability among prehistoric and historic hunter-gatherers, this has to be qualified. First of all, while this appears to be the case *in general*, it can hardly be assumed to apply uniformly to any individual case (see references above and e.g. Arponen et al. 2019; Johnson 2014). Understanding precisely what consequences variation in any single environmental variable has in any given case, if any, will be complicated by both the societal and environmental systemic wholes that respond to this variation, with some systems being more or less robust to such perturbations, depending also on the time-scale over which it operates and can be recognised archaeologically. While for example drought could intuitively be taken to represent a societal challenge, this certainly need not be the case. Drought might very well present more opportunities for resource exploitation than it eliminates (Arponen et al. 2019:5–6 with further references), illustrating the point that any systemic variation, environmental or societal, can represent both threat and opportunity to systemic wholes, and simultaneously represent threat and opportunity to different parts of the systems.

The further delineation of this thesis to focus on coastal areas has some further implications for what can be expected to be variables of concern for understanding the structure of the societies dealt with, indicated by the header of this section which includes the term 'fishers'. Hunter-fisher-gatherers is a term used by some scholars to underscore the economic significance of the utilisation of aquatic resources to some hunter-gatherer groups (Cummings 2013:22–24). The term is generally meant to be used in an inclusive fashion, and can in addition to fishing thus also pertain to the exploitation of other marine resources such as marine mammals, shellfish and seabirds. Given the concentration of Mesolithic sites in the coastal areas of Norway, and the relative importance of marine resources that can be assumed from this, the term hunter-fisher-gatherer has been preferred by several scholars working with the material (e.g. Bergsvik and Hufthammer 2009; Mansrud and Persson 2018).

One reason that the coastal setting is of importance is that environments with a rich and stable access to resources has been argued by many authors to be more likely to support semi-sedentary, hierarchical foragers with higher population densities. This is found to commonly be associated with concentrated marine resources (e.g. Keeley 1988; Singh and Glowacki 2022; Smith and Codding 2021), which are associated with a higher net productivity and ecological stability, with coastal areas representing ecotones that give rise to multiple niches conductive of species diversity (e.g. Yesner et al. 1980). However, as with the role of other environmental conditions for impacting the social structure of hunter-gatherers, important variation exists within these general trends. As a consequence, Jeffrey and Lahr (2020) have argued that there has been a tendency of oversimplifying and reducing the adaptational diversity among foragers utilising aquatic resources, reminiscent of the earlier oversimplifications of hunter-gatherers in general (see also Bailey and Milner 2002; Erlandson 2001). As this study is limited to studying the developments within the coastal region of south-eastern Norway, it is not in a position to inform the question of how coastal adaptation might be conductive of other societal configurations than terrestrial adaptation. It can, however, potentially illuminate regionally internal variation in coastal adaptation over time.

A note should be made on the fact that in the literature the terms *coastal adaptation* and *coastal resource use* are sometimes taken to imply different and quite specific things (see e.g. Faulkner et al. 2021; Marean 2014; Will et al. 2019). Coastal resource use is in this understanding seen as something that is conducted sporadically or occasionally, and that has limited transformative feedback effects on the life-ways of the societies in question. Conversely, coastal adaptation involves a degree of coastal engagement and commitment that has an altering effect on these societies. I do not use the terms in this manner here. The conceptual distinction is certainly an important one, especially as marine exploitation is believed to potentially, but not necessarily (e.g. Erlandson 2001), lead to technological ratcheting and increased societal complexity. However, these quite specific connotations of the terms stand in danger of leading to misunderstandings for readers that have another understanding of adaptation, which need not be defined by some threshold in the intensity of coastal engagement. One response to the specifics of a given coastal habitat might for example be movement and extended use of terrestrial resources, which would fall within a more inclusive definition of adaptation to a given coastal environment. While the above division might have merit in some analytical settings, the dependence on marine resources is arguably better understood along a continuum that I believe this distinction might unnecessarily dichotomise.

3.3.2 Land-use and mobility patterns

As it is fundamental for subsistence search, mobility patterns are considered defining of hunter-gatherer societies (e.g. Kelly 2013:77–113; Singh and Glowacki 2022). Important characteristics related to land-use and mobility patterns is the range of movement, its frequency, the degree to which movement ranges are territorially defined, where in the landscape movement and occupation occurs, the degree to which this is related to different kinds of activities, and the degree to which these aspects varies annually, with the seasons or other temporal frequencies. Furthermore, as mobility operates at the level of individuals, the degree to which people have moved as individuals or in groups, and what kinds of people have moved is ultimately also collapsed within the mobility term (Kelly 1992). From an archaeological perspective, however, occupational duration is often considered the most important dimension of hunter-gatherer mobility (Grove 2009). This follows both from the structuring effect this has on the activities carried out by members of these societies, from its frequent correlation with a range of other indicators of societal complexity, and from the expectation that occupational duration should be reflected in characteristics of the available archaeological material. However, the role of occupational duration as either a potential pre-requisite, cause or mere covariate with other dimensions of societal complexity cannot be assumed for any given case, and is also likely to play into a complex web of interrelated societal feedback effects.

One of the most central models with which to approach past hunter-gatherer mobility follows from Binford's (1980) distinction between foragers and collectors. Foragers are generally characterised by higher residential mobility, involving the movement of all members between residential bases, while collectors are associated with a higher degree of logistic mobility, involving the temporary excursion of task-groups from more permanent residential bases to fulfil specific tasks. Binford (1980) argued that foragers are more common in environmentally homogeneous regions, while collectors are more common in regions exhibiting temporal and spatial variation in available resources.

The mid-latitude coastal setting of this thesis could thus have some general implications for what might be expected in terms of mobility patterns. Based on historically known hunter-gatherers, Binford (1990) has argued that a semi-nomadic mobility pattern dominate in higher latitude settings. This involves a reduction in residential mobility in the winter months, where settlements are established close to stable resource patches or stored foods, and foragers utilising aquatic resources will, in general, be characterised by highly logistical mobility patterns. Furthermore, Binford (1990) also argued that in higher latitude settings there is generally a lower dependence on plant foods, and a tendency for this to be replaced by the exploitation of aquatic resources, rather than terrestrial hunting and trapping. The exploitation of aquatic resources such as fish and marine mammals can in turn have implications for technological complexity, where a dependency on elaborate boating and catching technologies can follow from the challenges posed by hunting aquatic resources (e.g. Arnold 1995; Kelly 2013:127).

Lane (2014) has argued that while there is a general consensus on the heuristic value of the forager/collector distinction, he also underscores that these are the extreme ends of a continuum, as Binford (1980) also originally contended, and that most forager populations have mobility patterns that fall somewhere between these extremes. While it might very well be the case that that higher latitude hunter-fisher-gatherers are generally associated with a higher logistical as opposed to residential mobility patterns, the degree to which this has been the case and might have varied throughout the coastal Mesolithic of south-eastern Norway must still be considered undetermined. While classic treatments of hunter-gatherer mobility such as that of Binford (1990) do touch on the issue of aquatic hunter-gatherers, it has been argued that they often underestimate the implications of aquatic adaptation, and crucially the implications this has for these models to meaningfully track mobility patterns that involve traversing intricate coastlines and voyages to off-shore islands using water-going vessels (see Ames 2002; Rowley-Conwy and Piper 2017; Yesner et al. 1980). However, despite the important nuances that might be subsumed within the forager–collector continuum, especially when applied to hunter-fisher-gatherers, Ames (2002) maintains its heuristic value. Consequently, the forager–collector continuum and occupational duration are aspects of mobility that are in focus for this thesis. This is the direct concern of Paper 3, which attempts to illuminate these dimensions by drawing on the composition of the lithic inventories associated with sites in the study area (Roalkvam 2022). However, as outlined above, there are still a host of dimensions of mobility that are not captured by this framework and which decidedly warrant future investigation.

3.3.3 Responses to sea-level change

In most areas of the world, post-glacial sea-level change has involved inundation of vast areas that were previously inhabited. For Europe alone, Bailey et al. (2020:2) give the estimate that around 2.5 million km^2 have been submerged following the Last Glacial Maximum, which equates to c. 40% of the present landmass. This has undoubtedly led to the destruction of vast amounts of archaeological material, and offers a considerable challenge to the retrieval of what archaeological material remains, and for efforts to reconstruct the past landscape in the impacted areas. This has been argued to have led to a reluctance on the part of archaeologists to contend with this challenging material, and to have resulted in an underestimation of the role that marine adaptation has played throughout prehistory (Bailey and Milner 2002).

As was presented in Chapter 2, unlike most areas of the world the study area for this thesis has been subject to a continuous and at times dramatic post-glacial relative sea-level fall. While methodological developments, new material and willingness to confront the issues posed by post-glacial relative sea-level rise have improved greatly in recent decades (see e.g. Bailey et al. 2020), the potential insight that can be gleaned from areas such as south-eastern Norway is therefore immense. This follows from the fact that the material has not been subject to the destruction and erosion that can follow from marine transgressions, and from the fact that retrieval of the material is comparatively easy, given that it is today located on dry land and has not been buried in thick layers of marine sediments. Mesolithic sites in the region are generally located at elevations that have historically not been impacted by the expansion of infrastructure or agriculture, and the sites are typically detectable through test-pit surveys that commonly encounter the material from c. 10–30 cm below the surface (e.g. Berg-Hansen 2009; Nummedal 1923). While this has come at the cost of preservation of organic material, which is typically poor in the acidic Norwegian soils, it does, at the same time, offer a virtually unprecedented potential for mapping the distribution of a large number of sites through the relatively easily recovered lithics. Furthermore, while the reconstruction of past sea-level change is hefted with some challenges, these areas have not been impacted by the deposition of marine sediments following their emergence from the sea, which means that the landscape inhabited by Mesolithic populations is also comparatively easy to reconstruct.

Depending on its magnitude, sea-level change can impact not only the habitational suitability of any individual location, but can have far-reaching effects that impact shoreline morphology, drainage systems and oceanic circulation, in turn having a wide range of potential effects on the prehistoric societies that inhabited these areas (e.g. Åkerlund 1996; Astrup 2018; Groß et al. 2018; Vaneeckhout et al. 2012). While the at times dramatic sea-level change would have required a response from human populations residing in the impacted areas, it is by no means given that these would have negative societal effects. In fact, areas impacted by sea-level change can become increasingly attractive for hunting, fishing and gathering precisely because of these factors. Conneller et al. (2016), for example, argue that the rapidly changing coastal landscape associated with the isolation of the Channel Islands from the mainland made these especially attractive for settlement by Mesolithic populations. As with any environmental change, how sea-level change impacts the population of any given area will thus depend on a wide range of factors pertaining to the amplitude of shoreline displacement, the topographic setting, and the nature of the environmental and societal systems that respond to these changes (see references above and Barnett et al. 2020).

Sea-level regression would have had the consequences that present-day fjords would have been wider in prehistory, and other fjords, straits and waterways that are closed off today would have been present. In south-eastern Norway, the sea-level regression has impacted the shoreline morphology in various ways and at various scales. At the larger scale, the Oslo fjord itself would have been a larger bay in the early Holocene, which would, for example, have had consequences for the first human migration extending along the Norwegian coast (Glørstad 2016). Comparatively, the closing of specific straits, the forming of peninsulas by islands being connected to the mainland, or the emergence of islands from the sea might have had important consequences at a more local scale (see e.g. Mjærum 2022). Furthermore, with the emergence of land from the sea, the transition from oceanic, to littoral to terrestrial environments means that the coastal areas would have been characterised by a process of ecological change that continued also well after an area emerged from the sea (Åkerlund 1996:79; Wren et al. 2020).

Beyond impacting the physical and environmental conditions of the areas that these societies inhabited, a central premise for Norwegian Stone Age archaeology has been that people have continuously settled on or close to the shoreline throughout the Mesolithic (e.g. W. C. Brøgger 1905). This has typically been related to resource exploitation, as well as travel and communication by boat. The degree to which this settlement pattern has been constant through the Mesolithic has fundamental societal implications, given the commitment to coastal adaptation such a settlement pattern can be assumed to reflect. However, it also underlies a method known as shoreline dating. Given the premise that sites were in use when located close to shoreline, it follows that a reconstruction of the trajectory of relative sea-level change can be drawn on to assign approximate date to when the sites were in use, based on their altitude relative to the present sea-level. Shoreline dating provides a valuable dating tool that allows us to date sites where typological indicators or radiometric dates are not available, and is fundamental to the chronological framework that underlies our understanding of the Norwegian Mesolithic. The first paper of this thesis involves a more principled evaluation of the relationship between sites and sea compared to what has been done in the past (Roalkvam 2023a), and the results of this analysis were then used to develop a more formalised method for shoreline dating that is made available as an R package through the second paper of the thesis (Roalkvam 2023b).

3.3.4 Palaeodemography

Palaeodemography or the study of temporal and spatial variation in the size and structure of past populations is a fundamental problem for archaeology (e.g. Drennan et al. 2015; French et al. 2021; Kintigh et al. 2014; Shennan 2000). This follows from the fact that demography is a central factor in processes such as genetic diversification, social network structure and scaling, as well as technological innovation and accumulation – human culture is in large part determined by human interaction, which is dependent on population density.

For example, the Late Glacial and early Post Glacial colonisation attempts of southern Scandinavia is characterised by a repeated sequence of technological loss which Riede (2009) has related to demographic dynamics, drawing on Henrich's (2004) model for reduction in technological complexity with demographic collapse (see also Premo and Kuhn 2010). However, when considering the potential role of population increase or decline for societal change, it is important to consider the wider context in which these developments operate. This can be illustrated by the distinction between population density and population pressure which Keeley (1988) emphasises. Population pressure is the combined effect of population density and available critical resources. Unless there is a catastrophic demographic collapse, increased population pressure can bring about changes to socio-economic complexity as an adaptational response, for example by economic intensification or diversification, storage or exchange, or with an increase in mobility (Halstead and O'Shea 1989) – population decline is therefore not necessarily or uniformly associated with reduction or increase in societal complexity (Collard, Ruttle, et al. 2013; Riede 2014). Understanding the consequences of changes in population dynamics and population structure is thus also dependent on knowledge of the nature and scale of the demographic development, as well as factors such as economic organisation and corresponding environmental carrying capacity. As a result, the role and potential feedback effects between population dynamics and other societal dimensions is contested in the literature (see e.g. Collard, Buchanan, et al. 2013; Currie and Meneganzin 2022; Read and Andersson 2020; Vaesen 2023), and Collard et al. (2016) have cautioned that population characteristics should be considered *potential* explanatory variables for observed cultural change. It cannot be assumed *a priori* that population structure determines observed cultural variation, or that it does so in a uniform way, and so it is important that such explanations are compared, contrasted and variably included in a range of potential explanatory frameworks.

A central question in the reconstruction of population dynamics among past hunter-gatherers is related to what is known as the forager population paradox (Blurton Jones 2016). This follows from the difference between the population growth rates among recent hunter-gatherer populations, which have been found to have an annual growth rate of around 1–3 %, and those that must have characterised prehistoric hunter-gatherer populations. Gurven and Davison (2019) give the example that with a growth rate near 1% per annum, a population of 100 would reach close to modern population numbers of 7.5 billion in under 2000 years. Some processes must therefore have led to the near stationary population numbers throughout evolutionary history, which Gurven and Davison (2019) argue is likely the result of oscillating cycles of population booms and busts (see also Chamberlain 2009). By contrasting archaeological population proxies with ethnographic and historical estimates, Tallavaara and Jørgensen (2021) have demonstrated how the scale over which these oscillations operate likely imply that common archaeological population proxies only puts us in a position to track average population size over the relative long term. This in turn has implications for the kind of questions we can hope to answer concerning variable population growth rates and their consequences (e.g. Brown 2017; Sibly and Hone 2002), and has to be kept in mind if archaeologically recognisable population changes are to be contrasted with other forms of cultural or environmental variation over time (Tallavaara and Jørgensen 2021).

Inferences concerning demographic developments in Norwegian Stone Age archaeology have traditionally been done by drawing on possible archaeological correlates such as the number and density of artefacts and sites (Olsen and Alsaker 1984; Østmo 1988). Following developments in prehistoric demographic modelling more widely (e.g. Crema 2022; Crema and Bevan 2021; Shennan et al. 2013; Timpson et al. 2014), such efforts have in recent years been directed towards analysing the summed probability distributions (SPDs) of ^{14}C-dates (e.g. Jørgensen et al. 2020; Lundström 2023; Nielsen et al. 2019; Nielsen 2021a; Solheim 2020; Solheim and Persson 2018). Modelling population dynamics by use of SPDs is based on the underlying logic that more people will have resulted in deposition and later retrieval of more dateable material (also known as the dates-as-data approach, after Rick 1987). However, there are a series of methodological and conceptual issues with this procedure, some of which have been dealt with, and others which are integrated into the methodology and need to be accounted for when interpreting any results (see recent review by Crema 2022).

One fundamental methodological issue follows from procedure of summing probabilities. Several authors have pointed to the fact that this operation entails a collapse of both the frequency of events and their uncertainties, thus rendering the final SPD difficult to interpret and not suitable for direct analysis (Blackwell and Buck 2003; Carleton et al. 2018; Crema 2022; Timpson et al. 2021). Another issue pertains to the underlying logic that there is a direct connection between the magnitude of material that ends up being dated and the number of people responsible for this, and the degree to which this relationship is stable over longer periods of time and across economic and cultural systems (e.g. Freeman et al. 2018; Surovell et al. 2009).

While various solutions and ways to contend with these issues have been proposed (cf. Crema 2022), their magnitude and relevance can be difficult to properly assess for any given context without also drawing on additional data that can inform the corresponding developments of other relevant factors. Consequently, what both critics and proponents of the approach appear to agree upon is the importance of contrasting a range of population proxies while also accounting for other variables that might impact these (e.g. Attenbrow and Hiscock 2015; Palmisano et al. 2017, 2021; Rick 1987; Timpson et al. 2015; Torfing 2015). The fourth and final paper for this thesis therefore compares the frequency distribution of shoreline and radiocarbon dates over time, both of which have previously been compared for the purposes of modelling past population dynamics in Fennoscandia (Jørgensen et al. 2020; Solheim and Persson 2018; Tallavaara and Pesonen 2020). This was done both to devise a methodology for using the newly developed method of shoreline dating for this purpose, and with the substantive goal of starting to unpack and understand how these proxies relate and what underlying factors could be driving their relationship.

3.4 Chapter summary

The first part of this chapter has outlined how fundamental problems relating to the resolution of the archaeological record in the dimensions of time, space and material culture has been contended with in the literature and how these are approached in this thesis. The second part of the chapter outlined some of the factors that are typically viewed as central for understanding past hunter-gatherer societies, and that dimensions related to mobility patterns, responses to sea-level change and demographic developments are the ones primarily dealt with in this thesis.

Preconceived notions of what has characterised hunter-fisher-gatherer societies will at some level necessarily impact how the material under study is interrogated. This follows both from what research questions are deemed central, and because these notions will have impacted how the material has been retrieved and recorded. These notions are therefore to some degree inescapable influences on any research into the Norwegian Mesolithic. However, in the next chapter I will argue how this should not lead to epistemic despair.

Chapter 4

Model-based archaeology

Over the years, several works have purported the benefits of a model-based archaeology (e.g. Clarke 1972a; Wylie 2002:91–96), which has especially gained a footing within various strands of computational, ecological and evolutionary archaeology (see e.g. Barton 2013; Brughmans 2021; Gonzalez-Perez 2018; Graham 2020; Kohler and van der Leeuw 2007; Lake 2015; Nakoinz 2018; Romanwoska 2015; Steele and Shennan 2009; Winterhalder and Smith 1992:12–16). The goal of the next two chapters is two-fold. First I will elucidate what defines or can define a model-based scientific approach, and in the following chapter I will demonstrate how this can form a useful framework for archaeological inquiry by drawing on examples from the papers of this thesis.

Central to the present chapter are four problem areas in the understanding of scientific models, as identified by Frigg and Hartmann (2018): 1) The ontological: what are models? 2) The semantic: what do models represent? 3) The epistemological: how do we learn with models? And 4) what consequences do the use of models have for overarching principles such as scientific realism, reductionism and explanation?

One fairly common understanding of models simply entails seeing them as a set of simplifications or assumptions concerning real-world phenomena (e.g. Barton 2013:154). Any representation could thus be considered a model whether it is generated physically, digitally, verbally, simply imagined, or is construed in a natural or formal language. Scholars arguing the case for model-based archaeology often start out by making the point that whether we acknowledge it or not, we always employ such abstractions when attempting to understand past reality (Kohler and van der Leeuw 2007:4; Lake 2015:7). The infinite complexity of reality means that any description of it has to be a simplification, and even if we were able to, a complete rendition of reality would not be a worthwhile endeavour in its own right. A perfect reconstruction of reality would be a tautology, which without perspective offers neither insight nor understanding (Slingerland

and Collard 2012:14–19; Yarrow 2006:77). Put differently, whether we understand archaeology as tasked with providing explanation, understanding, or interesting narratives about the past, any demand for more nuance, for its own sake, would be a refutation of theory (see Healy 2017).

These are, however, universal scientific points, variations of which have been made under diverse headings of archaeological theory (see e.g. Clarke 1978:13–16; Hodder 1999:67; Kristiansen 2004:98–99), and which extend far beyond the scientific endeavour, captured by what the artist Derek Jarman (2000:320, see Figure 4.1) described as the 'intellectual imperative of abstraction'. It would thus follow that if the term model is taken to denote all generalisations or abstractions of reality, which in its ubiquity would include any description or explanation, it is not given why this would have to be dealt with within a comprehensive model-based archaeology. The arguments in favour of a distinct model-based archaeology tend to follow from *how* this necessary simplification should be embraced, and in turn handled. What this entails can be foreshadowed here by invoking the classic quote from Box (1979:2): 'All models are wrong but some are useful'. But if all models are wrong, what is their epistemic value? To begin to answer this question, the above view of models, simply seeing them as abstractions, will be accepted for now without regard for their demarcation to data, theory and hypotheses.

4.1 Confronting beliefs with data

Smith (2015:18; 2017:522) has stated that one of the most central questions we can ask about our archaeological arguments is 'How would you know if you are wrong?'. Archaeological explanation often takes the form of what Binford (1981) termed a *post hoc* accommodative argument. This involves first gathering and categorising the data of interest, often using variables chosen by convention and convenience, and then building an explanation around any discerned patterns (Clark 2009:29). This data-dredging or pattern-searching approach is argued to constitute a limited inferential framework for a couple of reasons.

First, what among the virtually infinite aspects of the material available to us is considered interesting will always be determined by our beliefs concerning the processes that have resulted in their manifestation. What characteristics of the material is recorded and drawn on to organise it will dictate what patterns one can hope to reveal. As Popper (1989:46) framed it, without an underlying theory, how would we know what to look for? If one follows what has been done conventionally, without taking any explicit stance towards this, one will be dependent on how others have conceived of what questions are of interest and how these can be answered. Furthermore, this accommodative process can never falsify our argument, and Smith (2015:19) likens it with 'the farmer who paints bulls-

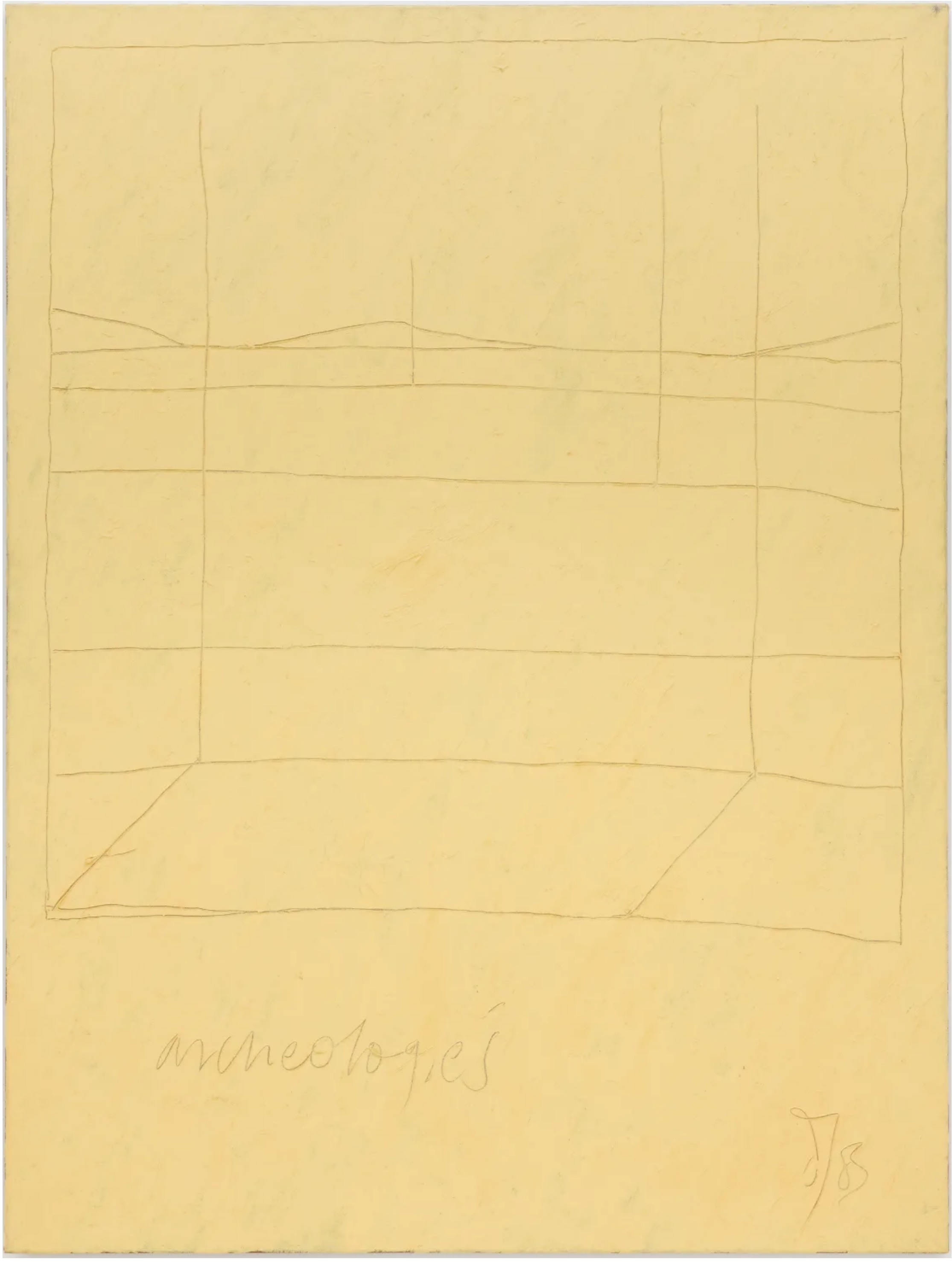


Figure 4.1: Derek Jarman, *Untitled (Yellow Painting - Archeologies)*, 1983. Oil on canvas, 134.6 x 101.6 cm.

eyes around the bullet holes in his barn in order to show his superior shooting skills.' *Post hoc* accommodative arguments can provide the identification of empirical patterns with respects to the employed units of analysis, which in turn can form the basis for social and behavioural hypotheses. But Binford (1981:85) has argued that such arguments can at best be 'treated as provocative ideas in need of evaluation'. Clark (2009:29) states that a necessary next step is to derive empirical implications of this hypothesis, which can be evaluated against a part of the archaeological record that is independent from the material originally used to derive it (also Barton 2013). Subsequent testing thereby provides an opportunity to reveal if one's accommodative belief is wrong.

The explicit testing of archaeological explanations was assertively introduced to the discipline with processualism, which argued that archaeology should adopt the explanatory goals of positivist social sciences. How this was to be done first follows from the standard processual view on what the archaeological material represents. Here, material culture was seen as an integrated part of – and the result of – total, multidimensional cultural systems (e.g. Binford 1962). As such, theories concerning how all aspects of cultural systems would influence and manifest in the material record should be conceived. Central to this is that the archaeological material represents an objective, albeit complex empirical record that reflects empirical causes, irrespective of our beliefs about what these causes are. The empirical material will in this processual understanding therefore offer a direct link back to this systemic whole. Archaeological material is representative of the multidimensional causal chain from cultural system to the archaeological record. The goal was therefore to develop theories concerning the prehistoric systemic whole and what processes have influenced the remnants available to us, which were then to be tested by drawing on the hypothetico-deductive approach. Furthermore, drawing on the deductive-nomological or covering-law framework, as taken from the logical positivist/empiricist view of Hempel (e.g. 1965), the ultimate goal was to establish laws pertaining to the conjunct occurrence of certain types of material remains with certain types of societal systems, irrespective of time and place.

It should be noted here that the programme of logical positivism, and the more mature logical empiricism (although see Uebel 2013 on this distinction), were far more nuanced that what they are often given credit for in the archaeological literature concerned with establishing why these views were misguided (Gibbon 1989:8–60). This is equally true for the over-simplified presentation that is given here. However, this can in part be justified with reference to the naive versions of these programmes that were adopted by positivist social science and archaeology at the time (Gibbon 1989:91–117).

According to Hempel (1965:231–243), the goal of science is to establish laws that are deductively valid, of the kind given by the classic example *All men are* *mortal / Socrates is a man / Therefore, Socrates is mortal.* If the premises are true, then the conclusion will always be true. However, when adapted to archaeology, the proposed laws were so banal that Flannery (1973:51) stated that attempts at adopting Hempelian empiricism 'has produced some of the worst archaeology on record' (cited by Smith 2022). The search for deterministic covering laws for societal systems was therefore abandoned by most practitioners. Furthermore, whether an argument is deductively valid or not is not dependent on whether the premises are true. If it happens to be true that all men are mortal and Socrates is a man, then the deductively valid argument is said to be sound. Determining whether the premises are true of the world depends on non-deductive reasoning. A deductively derived test that successfully corresponds with data only supports the hypothesis inductively, a point that appears to have been lost on early processualists (Chapman and Wylie 2016:27). However, giving up on the search for covering laws and deductive certainty need not entail that hypothetico-deductive testing is misguided, and more modest goals of confronting beliefs pertaining to specific contexts or research questions with data is, I will argue, still very much a viable goal.

4.1.1 Confirmation

Within a classic hypothetico-deductive system, an initial goal is to derive as many empirical implications of an explanation as possible. These implications are then to be tested by comparing these implications to actual observed data. Drawing on Carnap's (1936:425) 'gradually increasing confirmation', this entails that each time a model matches the data, the confidence that the model is true is increased. If, on the other hand, the model fails, it can be discarded as untrue. This should thus lead to the continual rejection of false models, and move us ever closer to, but not necessarily to, the actual model of reality. Although certainly an enticing prospect, there are problems related to this approach, irrespective of any goals of establishing covering laws.

A fundamental issue for hypothetico-deductivism, and scientific inference as a whole, follows from Hume's problem of induction (e.g. Ladyman 2002:31–61). As an empiricist, all knowledge about the world was for Hume derived from sensory perception. Any reasoning that extend beyond observation, past or present, is based on cause and effect. However, since we can never observe a causal connection between events, the conjoined occurrence of observations is all we have to draw on. As there is no logical necessity for regularity in patterns to hold beyond what we can observe, there is no logical foundation for inductive reasoning – there is no logical connection between the observable and unobservable. While we might observe the sun rise every day, there is no logical contradiction in believing it will not rise tomorrow. Hume held that while inductive reasoning will continue to be fundamental to science, and our every-day lives, it therefore has no logical justification. Following from the problem of induction, an issue for hypothetico-deductivism therefore pertains to the value of testing a hypothesis, and whether with successful tests our belief in the hypothesis should increase.

The logical empiricist attempts at working around the problem of induction and establishing a logical justification for confirmation was never successful, and a move to stating our beliefs in probabilistic terms never dissolved this fundamental issue. Central here is what is known as the paradoxes of confirmation (e.g. Sprenger 2023), of which Hempel's (1965:12–20) own raven paradox is a classic example (see Goodman 1984:59–83 for the so-called new problem of induction). If the hypothesis is that all ravens are black, this is logically equivalent to the statement that if something is not black it is not a raven. If we were to observe a black raven, this is evidence in support of the hypothesis. The paradox follows from the second statement: Given their logical equivalence, the observation of a green apple would be evidence in support of the hypothesis. Paradoxically then, we can study ravens by looking at apples. While problems of confirmation such as this are simple, they have proven difficult to resolve and a logically sound justification for confirmation is yet to be agreed upon (e.g. Godfrey-Smith 2003:39–56).

4.1.2 Falsification

One of the most influential contentions with the issue of testing is found with Popper and his concept of falsificationism. Popper, also a sceptic of induction, held that the problems of induction cannot be resolved. However, this is not of concern, as science in fact progresses not with confirmation but with falsification. In an attempt at demarcating science from non-science, Popper (e.g. 1989:33–66) stated that a theory can only be considered scientific if it has the potential to be refuted by observation. A theory that is compatible with all empirical variation is unscientific. The test of a hypothesis should be aimed at falsifying it, not confirming it, and a hypothesis that is not proven false should simply be subjected to even more stringent and elaborate tests. It is with each new rejection of a hypothesis that science progresses and we learn something about the world. Although it will inevitably be falsified, a good theory for Popper is therefore one that is bold, risky and corresponds with the world in surprising ways. There are, however, further issues related to the fundamental prospect of confronting our beliefs with data.

As insight from complex systems theory demonstrates, sensitivity to initial conditions can lead both different causes to produce similar empirical results, and similar causes to produce different empirical results (Premo 2010; van der Leeuw 2004:121). This reflects the problems of equifinality and underdetermination, as presented in the last chapter, where several explanations can agree on the empirical data, but disagree on the underlying causal mechanisms. This follows from the ubiquity of measuring error and the sensitivity of complex systems to minute variation. One classic example in this regard is the complex system of the weather, which can only be reliably predicted a few days into the future. Human behavioural and societal systems are often far more complex than that of the weather. Consequently, this renders the prospects of empirical confirmation or falsifiability weakened, and preference among different, even contradictory explanations can often not hope to be based on observable data. In the case of archaeology, explanatory models are additionally faced with our generalisations of an already sparse and fragmented archaeological record, further increasing the likelihood that several explanations account equally well and are underdetermined by the data at hand. However, underdetermination and sensitivity to initial conditions can also impact the assumptions underlying an explanation. To show how this is an issue we can draw on what is known as the Duhem problem (after Duhem 1914), or the Duhem-Quine thesis (following Quine 1953, and the holistic theory of testing; Psillos 1999:164), which states that nothing is necessarily learned from rejecting a hypothesis on the grounds of a test.

Drawing on Hvidsten (2014:184–187), we may postulate a simple model holding that mechanism A, under assumption B, implies C. In a test in which A occurs, it would in a hypothetico-deductive understanding increase our belief in the model if we could then reliably measure that C is true. In the case of Popper, the model is simply yet to be falsified. If, on the other hand, C is not true, this would imply that either A or B are untrue. We would not, however, be able to derive logically which of A and B are untrue. This would perhaps not appear to be an immediate reason for concern. As long as one aspect of the model is untrue, the model is untrue, and should be rejected. The problem is that we know that models always contain a multitude of untrue assumptions. Drawing on the classic quote from Box (1979) above and the earlier discussion on abstraction, all models involve subsuming the virtual infinite complexity of reality and thus cannot work without an equal amount of untrue assumptions that could impact a test (a point made in the context of archaeology by Salmon 1975).

In exemplifying the Duhem problem, Ladyman (2002:77–78) gives the example of testing Newtonian gravitational theory by observing the travel of a comet. The theory of gravity alone does not provide a prediction for this path. It also depends on factors such as the mass of the comet, the mass of other objects in the solar system, and their relative positions, velocities and initial positions, as well as Newton's other laws of motion. If the test was to fail, this failure can follow from an untrue hypothesis, but also from a misspecification of an assumption that is subsumed in the test – such as background conditions, measurement error, and initial conditions of the system. The Duhem-Quine thesis holds that any theory can be saved from refutation by adjusting its auxiliary assumptions (Psillos 1999:165). At some level a decision of whether the explanation has in fact been interfaced with observation is therefore needed. As stated by Ladyman (2002:80), 'falsification is only possible in science if there is intersubjective agreement among scientists about what is being tested.' While a severely complicating issue for falsificationism, as Popper also recognised, his proposition still holds if it is qualified by stating that for a hypothesis to be scientific, it has to have the potential to be refuted by some kind of observation. The challenge is determining what kind of observation this is (Godfrey-Smith 2003:66).

Drawing on this issue with testing and falsificationism, several authors have argued that these logical inferential schemas do not capture how science has actually progressed. This view can be related to naturalism, which can be conceived of as a perspective where philosophy of science should not be concerned with establishing universal, logically justified formalistic schema for how science should be conducted at remove from the scientific enterprise itself. In a naturalistic view, philosophy of science should rather draw on and be a continuation of scientific ideas themselves (Godfrey-Smith 2003:149–162). While formalistic logic can provide some important insights on what *can* constitute good components of strategies for scientific inquiry, such as aspects of Poppers falsificiationism, the scientific undertaking has been argued to be a far messier enterprise, where attempts at establishing a universal logical inferential foundation is doomed to fail. As a practical example, the orbit of Mercury was not properly accounted for by Newtonian gravitational theory. While this was known for many years, it was not until Einstein's theory of gravity that this orbit was correctly predicted (Ladyman 2002:89). Despite being unable to predict the orbit of Mercury, and thus being falsified, this did not cause the abandonment of Newton's theory of gravity.

Examples illustrating this point can easily be found in archaeology as well. For example, when new dates that dramatically push back the earliest human occupation in the Americas have been presented over the years (e.g. Holen et al. 2017; Parenti et al. 1991, 2018), these have often been met with scepticism as related to their veracity, and geological and other non-anthropogenic alternative explanations have been proposed (e.g. Agnolín and Agnolín 2023; Braje et al. 2017; Magnani et al. 2019). How convincing an explanation is and what causes it to be abandoned thus clearly depends on more than data alone, not least because data is more than a simple binary category that is either observed/not observed. What data is accepted, what it is understood to represent, and if it is adequately confronted with a hypothesis is in part dependent on a decision by the person who observes and the wider research community. What we observe should to some degree dictate what we believe about the world. However, the examples above demonstrate that stringent empiricism is untenable and is not in fact how scientific insight is achieved.

4.2 Instrumentalism and scientific realism

Arguments such as those presented above have in sum rendered suspect a unidimensional absolute demand for adherence to observable data and presents a significant challenge to the prospect of testing our beliefs about the world. This realisation also underlies common understandings of the virtues of a model-based archaeology, in which a search for the true model of the world should be abandoned. Rather than assessing the correspondence between model and the world, the concern is rather with assessing the degree to which the mechanisms of concern correspond with the world (Kohler and van der Leeuw 2007). However, if we are to concede to the fact that all models are wrong, how can we ever trust model-based inference?

In a classical instrumental understanding, the goal of science should be the prediction of phenomena that matter (e.g. Hausman 1998:187–190), a view famously forwarded by Friedman (1953). Whether prediction is achieved through the use of models that build on true causal mechanisms or not is irrelevant. As long as the predictions of the model has a satisfactory correspondence with the empirical variation of interest, it is deemed a success. This view is therefore compatible with the constraining realisation that all models are wrong, both because the truth of postulated causal mechanisms in and of itself does not matter, and because of the resulting relaxed demand for accordance with total empirical variation – degree of empirical correspondence determines the choice between models.

Related views have also been advanced within archaeology. The clearest example can be found in the domain of archaeological 'predictive' modelling, concerned with understanding where archaeological sites are located in the landscape (e.g. Verhagen and Whitley 2012). These studies have sometimes focused on identifying where sites are located in the present-day landscape, irrespective of past motivations, so as to potentially reduce costs of land-development, or to help guide archaeological surveys in large areas where a complete coverage of the landscape is not possible. The concern then is knowing where sites are and are not located, not why.

However, one of the criticisms forwarded towards instrumentalism is that if the ultimate goal is manipulation of relevant variables for the improvement of society, this will depend on uncovering true causal mechanisms. While mere prediction depends on stable correlation, control necessitates causality (Hausman 1998:190). As Elster (2015:18) puts it, explanation demands causation, and causation can never be revealed solely through prediction (see also Gibbon 1989:49). One way to conceive of causality is as dependent on a time-ordered counter-factual condition (e.g. Lewis 1974; Morgan and Winship 2015:4–6; but see also Pearl 2009), simply stated as A causes C if when A occurs then C occurs, and if A does not occur then neither does C. Instrumentalism and a focus on prediction and stable correlation can therefore never hope to explain social phenomena (see also Lake 2015:23–24). Of course, causal explanation does not necessarily have to be the main concern for archaeology. One could argue that academic interest in causal explanation should not always be the guiding principle behind archaeological inquiry but rather, for example, that mitigating costs associated with land-development or assembling interesting and poetic, albeit more speculative narratives about the past can be more important goals. My view in this context, as stated in the introduction to the thesis, follows from a form of realist understanding, where scientific inquiry is as a strategy by which we try to confront theoretical constructs with empirical observation, aimed at aligning our beliefs as reliably as possible with what is true (Godfrey-Smith 2003:161), where the ultimate aim is to answer why something that is true has occurred.

Scientific realism has been the dominating perspective in philosophy of science for decades (Preston 2013:7), and so an enormous range of different realist positions exists (e.g. Psillos 1999). At its core, scientific realism is typically taken to entail the philosophical stance that there exist real observable and unobservable entities and properties, and that claims concerning the veracity of either dimension cannot be set apart (Gibbon 1989:142–172; Psillos 1999; Wylie 2002:97–105). The goal is to reveal these truths, where truth typically follows a commonsensical definition of being determined by what is the case, and not, for example, what we believe to be true or what is most beneficial (Ladyman 2002:157–158; see also Malnes 2012:19–30). Regardless of whether or not it is possible to ever achieve, the goal of the realist is to reveal true, or approximately true (Psillos 1999:261–279), yet unobservable causal mechanisms that generate and shape the flux of observable phenomena. Scientific realism thus combines causal explanatory goals with ontological theses concerning the existence of observables and unobservables, and epistemological postulates on the possibility of gaining evidence for unobservables (Hausman 1998:191).

In a realist view, even the most careful empirical approach depends on theoretical assumptions that will determine what hypotheses are deemed relevant, what evidence empirical data are believed to represent, and how these are evaluated against hypotheses (Wylie 2002:100). With the early post-processual critique of processualism, Hodder (1984) argued that objective data is never tested against separate independent theories. These theories already underlie and determine how the archaeological material is recorded – there is no theory-free data. To the realist, however, the realisation that we might view the world differently does not take away from the belief that we inhabit a common reality that exists and is true independently of what we think about it (Godfrey-Smith 2003:174). Shanks and Tilley (1987:111) stated that 'there is literally nothing outside of theory' as archaeologists, according to Hodder (1983:6) simply 'create facts' (cited by Wylie and Chapman 2015:6), echoing Shapin and Schaffer (1985:355): 'it is ourselves and not reality that is responsible for what we know.' This, however, is a false dichotomy. As human knowledge is a part of reality, not something outside of it, it is better to understand human knowledge as the result of both ourselves and the world (Godfrey-Smith 2003:132; see also Hodder 1999:51–52). By extension, and by drawing on Fodor (1984), Godfrey-Smith (2003:158–162) states that it is not enough to say that observation is theory-laden. The challenge is determining what theories influence observation, how they do so, and how reality manifests in observation.

As an extension of this view, the form of feminist empiricist perspective advocated by Longino (e.g. 1990) through her 'contextual empiricism' follows from treating the social group as the foundational scientific unit. What constitutes a good explanation in a field of research is determined by the varying views and non-coercive consensus that is reached on these issues at the level of the research community. As we view the world differently, what ideas are brought to bear on an issue, and a decision of whether a theory has been adequately interfaced with data will thus follow from the diversity of that community. This is thus related to aspects of Mill's (1859) 'marketplace of ideas' (e.g. Gordon 1997) and Feyerabend's (1970) 'proliferation of ideas' as scientific virtues (Godfrey-Smith 2003:114). While there is a danger of simplistic generalisations of how, for example, sex differences influences how one views the world (Longino 1990:187–188), a healthy state for a research community would thus be one where a multiplicity of marginalised and privileged groups are represented.

4.3 What are models?

Building on the above, we can return to the issue of scientific models. While the classic hypothetico-deductive framework in a sense sees every model as a truth-candidate, they are for advocates of a model-based archaeology instead often understood as 'pieces of machinery that relate observations to theoretical ideas' (Clarke 1972a:1). A similar view can be found with Morrison and Morgan's (1999) view of 'models as mediators', where a model is a concrete or explicit representation of observables and theoretical beliefs and allows for a confrontation between these two dimensions. This is very much in line with the model as envisaged by Kohler and van der Leeuw (2007), who sees them as constructions that have similarities with, but exist independently of the target systems that they are to represent. Models are constructions used to draw further inferences about the reality they are to represent and are construed on the basis of what mechanisms we believe shaped the observables available to us. The hope is that when confronted with the world, the mechanisms of the model that the researcher is interested in correspond with those of the target system.

To explicate the concept of models as mediators, it can be useful to think in terms of an epistemological hierarchy, extending from observations to high-level theory. In a Mertonian view (Merton 1968), this extends from day-to-day working hypothesis of what data represents, to middle-range theories that act as bridging concepts for casting these within more comprehensive high-level social theories (e.g. Raab and Goodyear 1984; Smith 2015:22; see also Lucas 2015 for nuances on this). High-level theories can in this view be understood as 'overall perspectives from which one sees and interprets the world' (Abend 2008:179), with examples frequently encountered in archaeology being practice theory, cultural evolutionary theory, and so on. Popper (1989) was concerned with establishing how Marxism and Freudian psychoanalysis were unscientific, as they are compatible will all empirical variation. However, Godfrey-Smith (2003:71) holds that attempts at determining whether Marxism is scientific or not is a mistake. Rather, a given instantiation of Marxism – a Marxist model in the view taken here – should risk exposure to observation and have the potential to be falsified in a given context. One way to see models is thus as bridging concepts representing concrete instantiations of abstract theories, and as machinery for casting data as evidence to be confronted with these theoretical constructs.

In a realist conception of models, these can thus be seen as analytical tools, the purpose of which is to provide a concrete representation of the researchers beliefs, used to isolate or create a closed and credible surrogate system where causal mechanisms are allowed to work without impediment from surrounding noise (see e.g. Cartwright 2009; Mäki 2009; Sugden 2000; Sugden 2009 for discussion and variations on this). The aim, according to Cartwright (2009), is to reveal the capacities and differential contributions of unimpeded causal effects within such an idealised structure. However, this does not mean that the causal contribution is necessarily stable outside the surrogate system. In an open target system, the complex interplay of several causal mechanism can render the contribution from the modelled causal effects completely transformed, compared to their role in an idealised surrogate system (Gibbon 1989:150). Although stable correlations can point to the possible existence of a causal relationship, the relevance of the realist study of capacities, unlike positivist regularities, does not presuppose closed target systems (Groff 2004:12–16). Positivism can be seen as necessitating a closed system with regular conjunctions between events, such that an event of type A is always followed by an event of type B (Gibbon 1989:149). Cartwright (2009) contends that even though the realist surrogate system is credible, in the sense that the mechanisms could conceivably occur and result in the phenomena in question, the system is almost always different from all real cases in ways that matter. Drawing on the oft-invoked *ceteris paribus* statement – all other things are in fact not equal (cf. Cartwright 1983:44–77) – all models are wrong. The confrontation of model and data can therefore never avoid the problems of induction, and the question of interest then is not whether the model is true or false, but if the model resembles the world in the relevant dimensions, given its purpose (Clarke and Primo 2007:747; Kohler and van der Leeuw 2007:3).

For all the ambiguities nested in the above account of what can be taken to constitute models, a central element is the view that they are constructed and explicit representations of our beliefs. Precisely this is also central to the contention that one of the most important aspect of model-based approaches follow from their explorative side (Aydinonat 2007; Hausman 1992:77; Premo 2010). This results both from the assembly process itself, and from subsequent probing and manipulation of the model (Morrison and Morgan 1999). In the initial construction of a representation of theory and data, the researcher is forced to concretise their assumptions and beliefs. This will likely lead to the adjustment of inconsistencies, the discovery of additional theoretical implications or relevant empirical patterns and increase the opportunity for explicit handling and reporting of uncertainty. Through stringent and explicit aggregation of model features, further theoretical and empirical consequences are also likely to be revealed. Thus, in its construction, the model will already have provided valuable insights, regardless of its future archaeological life-span.

Following its construction, further insight can be achieved through direct manipulation of model parameters and assumptions (Morrison and Morgan 1999:32–35). This holds the potential of revealing additional causal propensities and limitations that are difficult to reveal by passive study of the model, and can reveal how sensitive it is to such adjustments (Gibbard and Varian 1978; Premo 2010). It has been argued that the potential of mathematical and computational models to stringently and coherently aggregate a multitude of mechanisms, and allow these to dynamically interact over time means that these can reveal unnoticed or counter-intuitive aggregate effects (Aydinonat 2007; Lake 2014, 2015), in effect generating new evidence that could not be discerned otherwise (Wylie 2017). The same exploratory potential is then extended by any attempts at evaluating the correspondence between model and target system, and by the involvement of an audience that comments, criticises, dismisses or helps align model and target system (Mäki 2009).

This explorative side of models can also be related to the realist concern with explanation, and not merely emulation and prediction, which has been emphasised by several advocates of model-based archaeology (e.g. Lake 2015:23–24; Premo

2005, 2010). An emulative adjustment of model parameters until the model acquires an adequate fit to the original data under study, followed by an assessment of the ability of the model to predict independent data, could result in a sufficient result from an instrumental view. However, the issues of equifinality and underdetermination underlies a view in which emulation of a process that accounts for the empirical variation of interest is not an satisfactory inferential aim if the goal is to reach true explanations of the past. As multiple processes could likely account for the empirical patterns under study, mere emulation does not inform what and how many competing explanations could be viable alternatives, and does not provide any basis for evaluating the probability that a proposed explanation should have resulted in the observed outcome. Consequently, an experimental approach has been advocated, in which a range of competing models are to be compared with an aim to assess their sensitivity to perturbations and parameter inclusion, exclusion and adjustments (see Lake 2015). Some structuring principles that can underlie such an experimental approach, and what criteria can be drawn on to adjudicate between competing models, can be approached with reference to the concepts of explanatory power and inference to the best explanation.

4.4 Inference to the best explanation

So far induction has here been used to denote all non-deductive reasoning and been exemplified by what is sometimes termed its enumerative or statistical form. That is, induction as the repeated observation of conjoined phenomena. However, other forms of non-deductive inference exist. Archaeology is often concerned with explaining singular or infrequent events, and not generalisations where an appeal to enumerative induction is possible. Clearly then, other lines of reasoning can be drawn on to arrive at and choose between alternative explanations. One such form of inference has been variably labelled abduction, explanatory inference or inference to the best explanation (Godfrey-Smith 2003:39–44; Harman 1965; Lipton 1991). Lipton (1991:58) formulates this mode of inference simply as 'Given our data and background beliefs, we infer what would, if true, provide the best of the competing explanations we can generate of those data.' (Fogelin 2007:604). Scientific realists often lean on this mode of inference to provide a way around the problems of induction and underdetermination (Psillos 1999:162–182), and this has been argued to constitute a good and often inadvertently employed framework for archaeological inquiry (e.g. Campanaro 2021; Fogelin 2007).

Fogelin (2007) argues that despite the theoretical differences that exists among archaeologists, inference to the best explanation is often the logic underlying their conclusions. For example, he demonstrates how when providing an explanation for smudge pits, a common archaeological feature in Eastern United States, Binford

(1967) draws on ethnographic analogy to arrive at an explanation that is better than any alternative explanations he can muster (Fogelin 2007:611–612). Despite using deductive-nomological language, Binford never independently tests any deductively derived hypothesis, and he arrives at his conclusion, Fogelin (2007:612) argues, because it is the explanation among the alternatives that corresponds with the widest breadth of relevant empirical data. Similarly, Hodder (1991), after having abandoned his most relativistic stance, adopts what he terms a 'guarded objectivity' through an appeal to hermeneutics. This starts with the context of the archaeologists themselves and their pre-existing beliefs and underlying theories, which is opposed to the context of the people responsible for the archaeological material available to us. By moving back and forth between such context and trying to cast our data in the light of these, the goal is to adjust an interpretative whole until the two contexts coalesce. The process is thus one of iteratively fitting empirical pieces within an interpretative whole, that is at the same time adjusted by these pieces. In this framework 'We measure our success in this enmeshing of theory and data (our context and their context) in terms of how much of the data is accounted for by our hypothesis in comparison to other hypotheses.' (Hodder 1991:8). This is arguably also an appeal to inference to the best explanation (Fogelin 2007:612–614).

Central here is, as above, that hypotheses have been argued to be best evaluated when comparing them to the ability of substantive competing alternatives to fulfil the same purpose, and not just their negation, the null-model (e.g. Perreault 2019:1–22; Smith 2015; Wylie 2002:95). Pitching alternatives against each other will lead away from a pure search for corroborative evidence for a single hypothesis, and will, following from Chamberlin's (1897) 'method of multiple working hypotheses', help the researcher avoid 'a pressing of the theory to make it fit the facts and a pressing of the facts to make them fit the theory' (Chamberlin 1897:843; see also Betts et al. 2021; Platt 1964). This thus avoids one of the dangers of emulation and *post hoc* accommodative arguments, which has been argued to lead to explanatory complacency and personal attachment to individual explanations (Smith 2015; see also Elster 2015:12).

However, if one arrives at hypotheses that account for the data equally well, that is, they are underdetermined, then other criteria will dictate what is the best choice among them. These are often termed theoretical virtues, which when combined is to capture the explanatory power of a hypothesis (Psillos 1999:171). A first criteria pertains to explanation, where a realist would hold that a hypothesis that makes claims about what has caused an empirical pattern will be given preference over a hypothesis that does not. If a locational model says that sites tend to be located close to rivers, and another explains this with reference to a specific kind of resource exploitation practice, then the second hypothesis would be given preference. Apart from the realist goal of explanation, this follows from the additional empirical implications this causal explanation holds, thus potentially increasing its explanatory breadth and increasing its falsifiability. From a Popperian view, it is riskier. Other and interrelated virtues pertain to coherence with established theories, the power of an explanation to unify multiple theories in a unified whole, the consilience of multiple lines of evidence, lack of *ad hoc* explanatory features, and ability to generate novel predictions (Psillos 1999:171). Simplicity is also often held to be one such theoretical virtue (Fogelin 2007; also discussed by Lake 2015), although it is not necessarily clear why truth should be simple rather than complex (Godfrey-Smith 2003; see also Sober 2015).

4.5 Evidential scaffolding

Theoretical discussions in archaeology have often framed the field as situated at extremes of positivism and relativism, or humanistic and scientific ideals, harking back to Snow's (1959) distinction between 'The Two Cultures' in western academia (e.g. Earle and Preucel 1987; Sørensen 2017). However, Chapman and Wylie (2016) and others (see below and Fogelin 2007 above) have argued that this perspective does not inform how archaeology has in fact progressed, nor that it constitutes a good reference frame for understanding how to do good archaeology. This is not to say that these discussions cannot hold important points for elucidating the nature of our inferential frameworks, or that theoretical stances do not influence what questions are deemed of interest and how the material record is approached. Rather, this then in a sense naturalistic argument is that these discussions are oversimplified, hyperbole and largely unrepresentative of an archaeology that generally progresses by drawing on a far more complex and eclectic web of theoretical and philosophical influences (see also e.g. Hegmon 2003; Johnson 2006; Pearce 2011; Pétursdóttir and Olsen 2018; Preston 2013). Therefore, the extremes of insisting on trying to establish deductively certain knowledge or a wholesale rejection of the possibility of ever moving beyond speculation does not represent an adequate reference frame for understanding what constitutes good archaeology, how to conduct it, nor how consensus and synthesis on claims about the past have been arrived at.

Given the realisation that we lack an infallible logical foundation with which to establish explanations, Chapman and Wylie (2016) speak for an iterative epistemological process where a temporary scaffolding for how data is cast as evidence by drawing on multiple methodologies and lines of reasoning is continuously adjusted, extended and reassembled. Crucially, these scaffolds are to be subjected to critical reflexivity, but be grounded in domain-specific norms of what constitutes evidence, so as to tackle what Binford (1981:21) presented as the challenge of 'how to keep our feet on the "empirical" ground and our heads in the "theoretical" sky.' (Chapman and Wylie 2016:8). They further draw on Norton (2003) to argue that progression in science has been achieved mainly through the domain-specific development of robust reference frames for grounding further inference, not through the development of increasingly sophisticated universal inferential schemas (Chapman and Wylie 2016:39).

By drawing on Toulmin (1958:213), who argues that we should 'abandon the ideal of analytic argument' and the goal of deductive certainty, a central component of Chapman and Wylie's (2016:36–37) argument is illustrated by a quote from Toulmin (1958:248):

> 'The proper course for epistemology is neither to embrace nor to armour oneself against scepticism, but to moderate one's ambitions – demanding of argument and claims of knowledge in any field not that they should measure up against analytic standards but, more realistically, that they shall achieve whatever sort of cogency or well-foundedness that can relevantly be asked for in that field.'

Important here is therefore that there is no universal recipe for inferential adequacy, but that inference is domain specific. What we can hope to achieve is that our inferences are credible, but this limitation should not entail a regress into wholesale scepticism. The goal is to arrive at beliefs that are more reasonable to trust than doubt, without demanding that they should be infallible and beyond critical scrutiny.

Building on the theoretical plurality of archaeology, and echoing the point made by Godfrey-Smith (2003) referenced above, Chapman and Wylie (2016:41–43) argue that theory-ladenness will differentially impact what archaeologists consider evidence. Some biophysical observations will be relatively transferable between contexts, and their role as archaeological evidence less integrated with theoretical preconceptions. Inferences to do with symbolic behaviour are less transferable as they will be less secure, and more contingent on the given cultural context and the evidential scaffolding supporting them to be considered evidentially adequate. However, this does not mean that symbolic behaviour is in any sense more off-limits than for example chronological inferences that draw on radiometric dating. Neither can reach deductive certainty, and their role as evidence for past events is simply differentially dependent on the warrants and assumptions that underlie them (Chapman and Wylie 2016:42).

While the inferential virtues outlined in the section above can constitute some guiding principles for how to arrive at good explanations, Chapman and Wylie (2016) hold that these cannot be schematically and universally brought to bear on archaeological explanation. Different questions will necessitate different evidence, and different evidence will necessitate different warrants. What Wylie (Chapman and Wylie 2016; 2017) has held as a central component of evidential scaffolding is that these should be robust and draw on multiple lines of evidence. In his review of Chapman and Wylie (2016), Currie (2017a) likens this with the view of Cartwright (2015) who prefers arguments that are 'short, stocky and tangled' over elegant and tidy arguments that are 'tall and skinny'. That is, at the price of complication, a diverse and broad evidential foundation is more secure than an elegant but fragile chain of evidential premises (see also Bayliss and Whittle 2015; Currie 2017b).

4.6 Quantitative archaeology and models

The understanding of archaeological inquiry outlined above need not be cast within a model-based understanding. The term model has been noted to increasingly involve aspects that were previously seen as a domain of theory (Preston 2013:10), and aspects of their role as conceived of here also relate to and cannot necessarily be set apart from other concepts for bridging data and beliefs, such as hermeneutics, Mertonian middle-range theory and evidential scaffolding. Furthermore, it has also been argued that models are best understood as a separate and distinct kind of reasoning (Godfrey-Smith 2009) and that models should not be conflated with all kinds of 'representational vehicles' (Godfrey-Smith 2003:186–189).

However, despite its ambiguities, I still believe the model term offers a sensible way of thinking about the issues dealt with in thesis. It forces a view where explanations are cast as fallible explicit constructs, which are thus both more easily interrogated, and are less likely to lead to explanatory complacency. Furthermore, this concretisation and fallibility is also very much compatible with the ideals of open science. Precise and explicit constructs of our beliefs as interrogative machinery lends itself well to a transparent and cumulative research endeavour as these are more readily communicated and disseminated.

Furthermore, this view also directly maps on to developments in statistics, where a model-based framework has been argued to constitute a better and increasingly more dominating framework than the traditional null-hypothesis significance testing (NHST) approach, which has dominated much of the discipline for the last century or so (e.g. Burnham and Anderson 2002:1–22; McElreath 2020:1–17; Rodgers 2010). To briefly run through this argument, the epistemological basis for NHST starts with assuming a null hypothesis under which chance alone has generated the data, or that there is no meaningful difference between two compared groups beyond that which chance has caused. If under some statistical model the observed data is found to be unlikely to be in compliance with this null hypothesis, then the alternative hypothesis, that of the researcher, is favoured. Many authors have pointed to the severe limitations of this approach over the years (e.g. Cohen 1994; Rozeboom 1960) – a critique that has garnered renewed vigour with the replication crisis that has impacted large swathes of the social sciences (e.g. Nuzzo 2014; Wasserstein and Lazar 2016).

Some of the central issues include that rejecting the null hypothesis does not give logical support to the alternative, nor does failing to reject the null give logical support to the null. Multiple random or neutral processes can be responsible for the data, and data inconsistent with chance can be the result of multiple non-random processes – a decision concerning the rejection of the null therefore gives limited, if any, explanatory insight. This follows from what is considered the backwards logic of NHST, as it evaluates the probability of the data given the hypothesis, not the probability of the hypothesis given the data. The probability therefore does not concern the veracity of the hypotheses themselves. Additionally, a large enough sample size will always lead to a rejection of the null (Cohen 1994). As Tukey (1991:100) put it 'the effects of A and B are always different – in some decimal place – for any A and B. Thus asking "Are the effects of A and B different?" is foolish'. Statistical significance is not equivalent to substantive significance, as the magnitude of the probability associated with a NHST test does not necessarily have any bearing on the size, importance, or lack thereof, of a substantive effect. Furthermore, this kind of dichotomised view of significant/non-significant is argued to often be equated to the truth of a hypothesis, and once a result is reached, subsequent substantive interpretations can quickly extend beyond what the significance test itself warrants (see Crema 2022; Timpson et al. 2021 on this point in the context of demographic modelling in archaeology).

Some measures to counteract these issues is an increased focus on estimation and fuller reporting of statistical power, effect-sizes and confidence intervals, as well as a focus on explicating the processes we believe underlie the data. This is argued to be facilitated by a model-based statistical understanding, an understanding that Rodgers (2010:1) argues underlies a 'quiet methodological revolution' in statistics. He illustrates the concept by example of the arithmetic mean of a distribution (Rodgers 2010:4). Under the NHTS this is typically denoted as a descriptive statistic. In a modelling understanding, the mean can instead be conceived of as one of many possible mathematical models for the data, with the mean being a representation of the central tendency of a distribution. The shift to a model-based perspective leads to the question of whether this model achieves what the researcher is interested in, and whether it does so better than its reasonable competitors, which in the case of the mean could be the median (Rodgers 2010). Put differently, the map is never the territory, but a highly abstract model such as the subway map can prove very useful for the purposes of commuting, and more useful for commuting than a topographic map (Clarke and Primo 2007:742). Echoing the point made above, we should therefore not evaluate our models against a null model, its negation, we should instead cast it against alternative models for fulfilling the same purpose.

The importance of estimation and model evaluation over significance testing has also been promoted in archaeology over the years (e.g. Buck et al. 1996; Cowgill 1977), and a concern with multi-model inference and model comparison is increasingly evident in the literature (e.g. Crema and Shoda 2021; DiNapoli et al. 2021; Eve and Crema 2014; Jørgensen 2020b; Timpson et al. 2021). In a similar vein to Rodgers (2010), Kohler and van der Leeuw (2007:3) have argued that a drift towards model-based inference has also been quietly happening in archaeology. Furthermore, given the view that the goal is to compare the explanatory power of viable alternatives, not focus on building and corroborating single monolithic explanations, this model-based view is also compatible with Fogelin's (2007) argument that in practice, abduction is the form of reasoning that underlies most archaeological inference, whether this is acknowledged or not.

4.7 Chapter summary

In closing, the model-based understanding outlined here builds on the realisation that data is influenced both by the world and what we believe about it, and that the fallible beliefs we have about the world are built by entire research communities over time. Furthermore, this model-based understanding not only involves the recognition of the necessity of simplification, but is, to repeat Jarman (2000:320), to 'embrace the intellectual imperative of abstraction'. As fallible constructs, the goal is to arrive at a model that is better than any competitors we can muster, not ones that are deductively certain. By extension, a model-based approach is therefore concerned with being transparent and precise in the arguments and assumptions that are being made, and therefore represents a strategy that both helps the modeller clarify their inferential framework to themselves, and facilitates critical engagement by others. Furthermore, as was indicated towards the end of this chapter, casting our questions in this light is also directly compatible with a wealth of techniques in quantitative research more broadly, in which an increasingly model-based understanding recognises and helps handle and make explicit the subjectivity, ambiguity and uncertainty in our proposed explanations (e.g. Flora 2018; McElreath 2020). In the next chapter, each paper of the thesis will be presented in light of the perspectives outlined here.

Chapter 5

Modelling the Norwegian Mesolithic

The last chapter laid out the foundation for what can constitute components of a model-based archaeology. This chapter will explore some ways in which casting the papers of the thesis in this light can help elucidate assumptions and further lines of inquiry associated with the arguments and empirical patterns identified in the papers.

The central modelling efforts for the papers are presented in Figure 5.1. These are presented in simplified form to represent a point of departure for this chapter. A range of ambiguities, nuance and questions concerning the reliability of the results are presented in more detail below.

Figure 5.1A gives the gamma distribution describing the vertical relationship between Mesolithic sites and the contemporaneous shoreline in the study region. This underlies the method for shoreline dating that is proposed in Paper 1 and 2. Figure 5.1B presents the variation in what is termed a curation index derived in the third paper. Higher values on this index is suggested to reflect a higher degree of residential mobility. The logistic model in Figure 5.1C describes the temporal frequency distribution of radiocarbon dates within the study area, which is proposed to mainly reflect overall population dynamics. Figure 5.1D presents an exponential model fit to the summed probability of shoreline dates from the study area. The model is rejected, meaning that although it was the best of the explored alternatives, it does not adequately capture this development. Albeit somewhat provisionally, the temporal distribution of shoreline dated sites is suggested to be influenced by population density but be most heavily determined by variation in mobility patterns.

In the following, the evidential foundations and inferential leaps that underlie the archaeological claims made in the papers are first explicated by presenting each paper using an evidential argument schema (Chapman and Wylie 2016; Smith

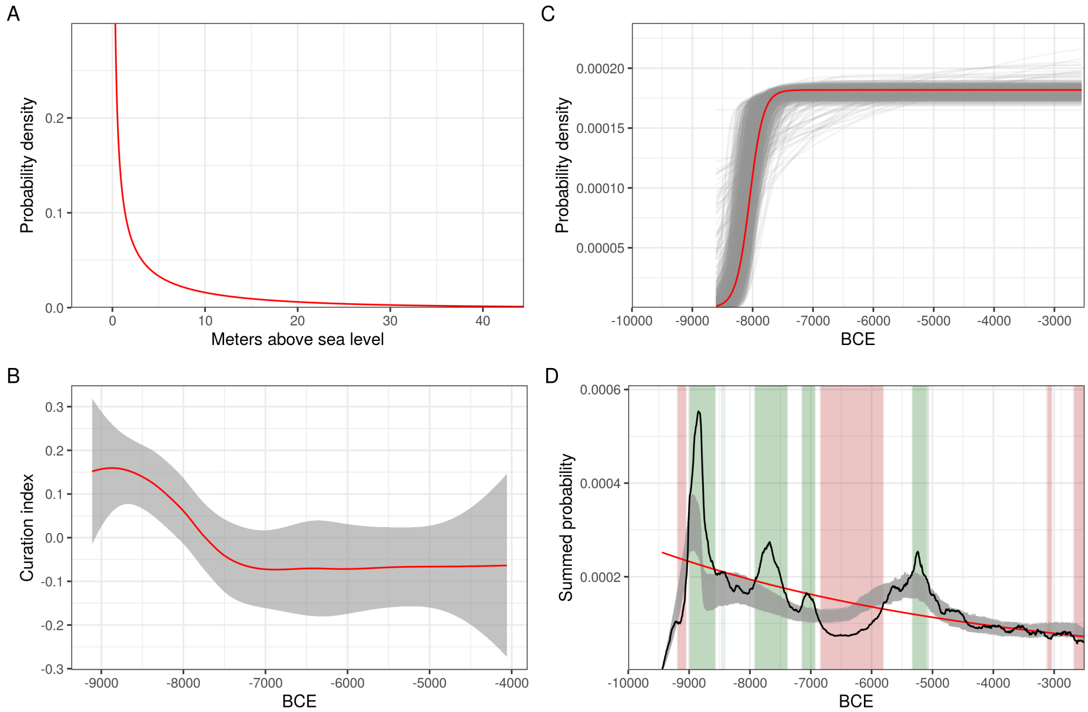


Figure 5.1: Models derived in the papers of the thesis. For clarity in the figures, the data underlying the models are left out. This is with the exception of for D, as this model was rejected as adequately explaining the data. A) The gamma distribution used to describe the likely elevation of sites older than 2500 BCE above the contemporenous sea-level within the study area (Paper 1 and 2). B) The average of 1000 LOESS curves and 95% confidence intervals fit to the curation index that is used to characterise lithic inventories within a subsection of the study area (Paper 3). C) Logistic model (red line) fit by maximum likelihood (ML) and 1000 samples from the joint posterior parameter distribution derived through Markov chain Monte Carlo sampling (grey lines, see Timpson et al. 2021), describing the summed probability distribution of radiocarbon dates from within the study area (Paper 4). D) The rejected exponential function (red line) fit by ML describing the summed probability distribution of shoreline dates (black line) within the study area (Paper 4). Deviations from the 95% critcal envelope derived from the exponential model through Monte Carlo simulation is given a red colour for negative deviation and green for positive.

2022; Toulmin 1958). Subsequently, a causal model for the main components of each paper is presented in the form of directed acyclic graphs (DAGs, e.g. Morgan and Winship 2015; Pearl 2009). These outline some substantive explanations that I believe might underlie the patterns that are observed in each paper, with the purpose of identifying some implications and avenues along which the results can be further interrogated in the future. First, therefore, the concepts of evidential argument schemas and graphical causal models are given a brief presention.

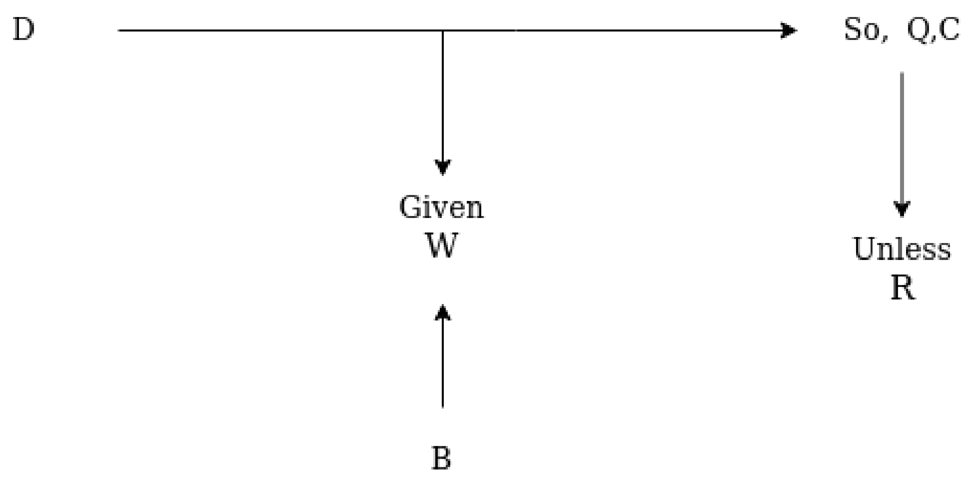
5.1 Evidential argument schema

The presentation of each paper below starts with laying out an evidential argument schema for the central evidential claims being made in the papers. The purpose of this is to clarify the argument being made, highlight central and potential objections and uncertainties, ways in which the study accounts for these, and ways in which this could be further investigated and improved in future studies. The components of the argument schemas are presented in Figure 5.2.

Following Toulmin (1958), 'warrants' are here understood as bridging concepts that allows one to move from observed data to substantive evidential claim. Warrants are in themselves claims that 'license the inference from facts to conclusions' (Chapman and Wylie 2016:34) that therefore also depend on underlying substantive, domain-specific arguments. All claims, including warrants, can in turn be challenged by 'rebuttals', which represent potential exceptions or objections to the claims being made. To maintain the inferential claim, rebuttals can in turn be answered with additional evidence and theoretical support, termed 'backing'.

Some adjustments to this framework have been made here. First, I have added the category 'potential backing'. These are meant to indicate steps that might be taken in future studies to further accommodate rebuttals and strengthen the belief that the warrants hold. Secondly, drawing on Chapman and Wylie (2016:176), the category 'deflection' indicates cases where I argue that rebuttals can be disregarded due to an assumed limited impact and relevance. That is, in these cases the rebuttals are not met with additional backing. Finally, the category 'qualifiers' from Figure 5.3 is not included, as there were as of yet no grounds on which to properly assess the strength of the evidential claims being made in the papers.

In the presentation of the papers below, these schemas will not be complete, but draw on what I view as the most central components of the arguments. Further nuances and caveats can be found in prose in the papers themselves, while the data and code published with each paper also offer further sources that can be scrutinised for additional underlying assumptions and potential inconsistencies (see Section 1.4).



- **D**atum: the facts cited in support of a claim.
- **C**laim: The conclusion drawn.
- **W**arrant: domain-specific bridging statements that allows the inference from D to C.
- **R**ebuttal: conditions of exception.
- **Q**ualifiers: specification of the strength of the claim.
- **B**acking: domain-specific support for the warrants.

Figure 5.2: Outline of Toulmin's argument schema. The figure is redrawn from Chapman and Wylie (2016:fig.1.1) which is in turn based on Toulmin (1958:94–145).

5.2 Directed acyclic graphs

The second part of the presentation of each paper involves constructing a causal graph that explicate what I believe are the main proximal causal drivers behind the patterns that were observed in each study. As was outlined conceptually in Chapter 4, building comprehensive theories of what we believe underlie a data generating process is central both to meaningfully treat the data, test explanations, and offers a clear path for establishing alternative explanatory frameworks which can be compared and contrasted.

The presentation draws on structural causal modelling, which originated with Pearl (see Pearl 2009; and Pearl and Mackenzie 2018 for an accessible introduction), through the use of causal graphs in the form of directed acyclic graphs. While causal graphs in various forms have a long history of use in archaeology (see e.g. contributions in Clarke 1972b; and Jørgensen 2020b; Kelly 2013; Price and Brown 1985b), the more principled framework of structural causal modelling has seen limited application in the discipline while being increasingly applied in the social sciences more generally (see e.g. Elwert 2013; Greenland et al. 1999; Huntington-Klein 2022; McElreath 2020; Morgan and Winship 2015; Pearl 2009; Rohrer 2018). As the causal graphs presented here are only meant to be cautious suggestions that can potentially structure future studies and accommodate further discussion, their full potential is far from being utilised.

First, it is necessary to establish some foundational premises and terminology. The goal of structural causal modelling is to allow the correlative and associative relationships that can be assessed by use of statistical tools to inform the causal effects that might exist between variables. A blind inclusion of all and as many covariates as one can come up with, without taking an explicit stance towards causation, stands in danger of undermining any drawn conclusions. This follows from the fact that the complete causal web will dictate what variables will have to be controlled for, that is, holding their effect constant either through sampling design or statistical control, and which variables would introduce bias if they are controlled. This is demonstrated through the use of DAGs below.

DAGs represent a specific kind of causal graph, where the term 'directed' refers to the rule that causal effects cannot be bi-directional – that is, causes points to effects. 'Acylic' refers to the rule that no directed path can form a closed loop. To illustrate the concept, a series of basic causal relationships are represented as DAGs in Figure 5.3. While many details have been left of this presentation, all DAGs, irrespective of their complexity, can be constructed and analysed using the basic relationships of chains X → Y → Z (and the condensed X → Y), forks X ← Z → Y, and inverted forks X → Z ← Y (Elwert 2013:249), all of which are represented in Figure 5.3.

The direction of the arrows (edges) in the model illustrates what variables (nodes) have a causal effect on other variables. An arrow going directly between two variables means that there is a direct effect. X is therefore said to have a direct causal effect on Y in Figure 5.3A. In other words, X causes Y. Treating Y as the dependent response variable and X as the independent explanatory variable in a statistical treatment would in this case be able to provide an estimate of the causal effect of X on Y.

In Figure 5.3C, X has a direct effect on Y, but as Z impacts both, Z is a confounding variable. That is to say, part of the impact of X on Y may simply be the result of Z affecting both, thus distorting the causal relationship between X and Y if Z is not controlled for. In Figure 5.3D, both X and Y cause Z. Z is therefore said to be a collider. Here, controlling for Z would lead to a distortion of the association between X and Y. This is because controlling for a common outcome of two variables can introduce a spurious association between the variables, known as collider or endogenous selection bias (Elwert 2013:250; see e.g. Griffith et al. 2020 for an intuitive example). In Figure 5.3B, part of the effect of X on Y goes through Z, which is therefore said to be indirect, mediated by Z. Controlling for Z would in this case block the causal pathway and could lead to an underestimation of the magnitude of the causal effect of X on Y. While there might be situations in which it could be of interest to isolate the effect that remains after accounting for the mediating variable (Baron and Kenny 1986; Hayes 2009), it has been demonstrated that this kind of mediation analysis stands in danger of introducing endogenous selection bias (Elwert 2013:264). A rule of thumb is therefore to not control for mediating variables.

It might seem disconcerting that DAGs cannot readily accommodate cycles or feedback-loops. While frameworks for directly accommodating this do exist (White and Chalak 2009), Morgan and Winship (2015:80) recommend a focus and willingness to first attempt to establish empirically tractable directed graphs in most settings. This follows from the fact that the future cannot cause the past, and so what might appear to represent feedback effects will generally be an issue of temporal resolution (Elwert 2013:249; Greenland et al. 1999). One solution when employing DAGs can thus be to take repeated measures at multiple time-points which can then be added as individual nodes in the model, such that, for example, increasing population density following an initial phase of colonisation might initially lead to a reduction in residential mobility, and reduction in residential mobility could then cause a further increase in population density at a later time-point. Thus, with increased temporal resolution, DAGs can accommodate such complex situations (Rohrer 2018:30). An inability to establish the time-order of effects, either empirically or theoretically, means that certain causal questions might be out of reach for a fragmented archaeological record of variable quality (see Section 3.1).

Explicating the causal processes and relationships that we believe underlie our explanations is critical for the construction of study designs and statistical models that correctly account for the causal relationships between variables, as not doing so stands in danger of severely distorting our findings. Provided the variables can be sensibly operationalised, DAGs offer a precise statement of how the interrelation between variables should be modelled statistically or how a sampling design should be structured so as to correctly estimate causal influences while removing the effects of non-causal associations that distort these estimates. Furthermore, causal modelling and the explicit formulation of what mechanisms we believe underlie the data generating process make DAGs an effective tool for clarifying research questions, for explicating relevant concepts, for identifying assumptions underlying an explanation, and for deriving testable implications of an explanation.

It is, however, important to note here that the DAGs presented below are highly speculative and have limited theoretical specification. They are presented in a purely qualitative manner, lacking information about the direction, strength and shape of proposed causal relationships, as well as their operationalisation. Furthermore, as they represent a first iteration, they are only meant to be tenuous suggestions that can potentially pave the way for exploring these issues. This will first involve the challenging task of establishing if and how the variables can be reliably measured, which reflects the fundamental issue of measurement and how archaeological data can be cast as evidence for past events. While the DAGs presented here will undoubtedly be proven to be inadequate in a myriad of ways, I still believe in the benefits of attempting to explicate our suggested explanations in this manner, as they can provide a starting point for further analysis, and for iterative refinement as our understanding grows.

5.3 Modelling the relationship between Mesolithic sites and the prehistoric shoreline

In the first paper of this thesis I have proposed a method for shoreline dating Mesolithic sites on the Norwegian Skagerrak coast, based on an empirically derived model of the relationship between the sites and the prehistoric shoreline (Roalkvam 2023a). This was based on simulating the distance between sites and the shoreline using 66 ^{14}C-dated sites and local reconstructions of shoreline displacement. The ^{14}C-dates operate as evidence for site-use that is independent of the position of the shoreline at the time, effectively offering a way to test and quantify the long-held belief that coastal Stone Age sites in Norway were located by the shoreline. The study found the sites to typically be located on or close to the shoreline up until some time just after 4000 BCE, when a few sites are located further inland

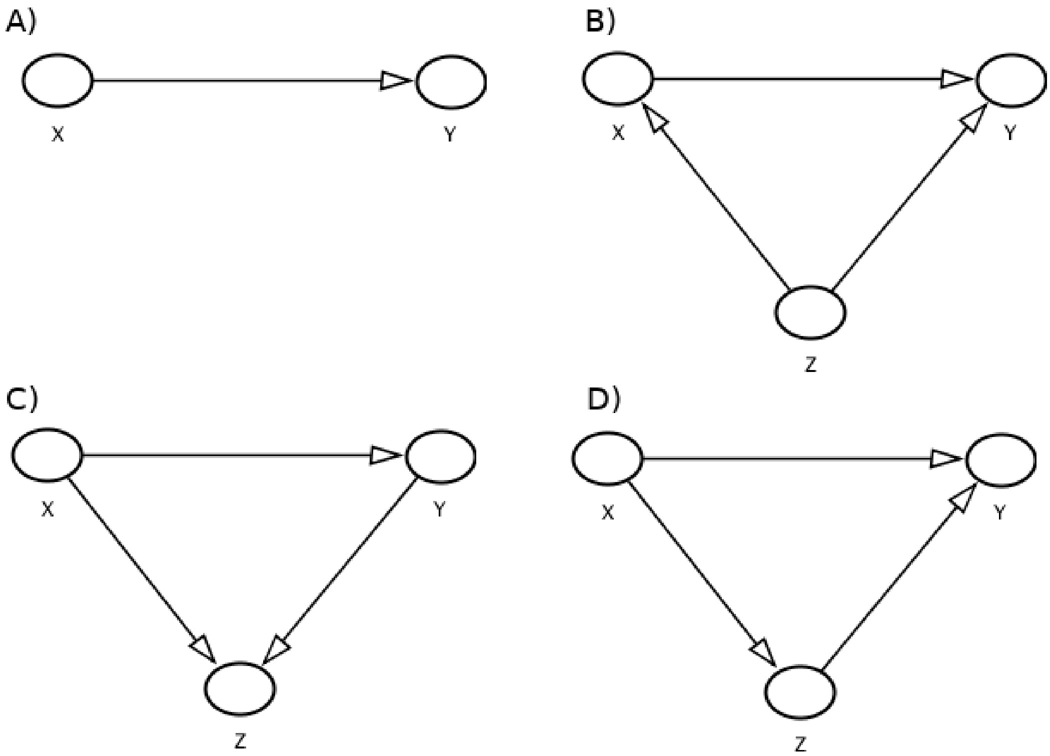


Figure 5.3: Basic patterns of causal relationships represented as directed acyclic graphs. A) Direct effect of X on Y. B) The effect of X on Y is confounded by Z. C) The effect of X and Y collide at Z. D) Part of the effect of X on Y is indirect, mediated through Z.

from the shoreline. At around 2500 BCE there is a clear break, and the sites are from this point on situated further from and at variable distances from the shoreline. Building on these findings, the likely elevation of sites dating to earlier than 2500 BCE were, in aggregate, found to be reasonably approximated by the gamma function given in Figure 5.1A. This is the model that forms the foundation of the proposed method for shoreline dating, which is released as an R package with the second paper of the thesis (Roalkvam 2023b).

The evidence and arguments underlying the study are presented as an argument schema in Figure 5.4. This centres on six major warrants that are necessary foundations for the evidential claim to hold. The first of these, Warrant 1, pertains to the radiocarbon dates from the sites and whether these correspond to the typological indicators in the lithic inventory of the sites, or should for some other reasons be disregarded as not being related to the occupation of the sites. For Paper 1, this choice was largely based on following the discretion of the archaeologists who have undertaken the excavations. Excluding the dates viewed as unrelated to the occupation of the sites substantially increased the degree to which sites were found to have been located by the shoreline, and thus functions in support for the evidential claim. A potential concern could be that the close association between coastal sites and the shoreline is a fundamental premise in Norwegian Stone Age archaeology, and might therefore have impacted how deviating dates are treated in the excavation reports. A brief presentation of the dates and the arguments for why they are believed to correspond or not to the use of each site is provided in the supplementary material to the paper (Backing 1.3). While I believe this procedure to be adequate and the interpretations in the excavation reports to generally be sensible, it might be a worthwhile improvement to instead predefine a set of evaluation criteria for the quality and relevance of the ^{14}C-dates if a similar study was to be undertaken in the future (Potential backing 1.4, following e.g. Pettitt et al. 2003; Seitsonen et al. 2012). This would reduce the number of *ad hoc* assessments of the radiocarbon dates.

A related point that is not included in the schema that is worth commenting on is how several radiocarbon dates from a single site were treated. Dates not intersecting at 99.7% probability were seen as representative of unrelated occupation events. Intersecting dates were then modelled using the OxCal (v.4.4, Bronk Ramsey 2021) function Boundary, and then summed using the Sum function. However, the procedure of summing dates is argued by some authors to be difficult to justify statistically, and procedures for defining the likely start, span and end-dates for occupational phases might be more sensible (e.g. Blackwell and Buck 2003). Furthermore, typological indicators in the assemblages could also have been explicitly included in the modelling of the dates (e.g. Bronk Ramsey 2009; Buck et al. 1996).

Warrant 2 pertains to the geological reconstructions of shoreline displacement and the interpolation between these to the analysed sites (the displacement curves are presented in Section 2.1.2). This is a necessary premise for it to be possible to evaluate the correspondence between site-use and the sea. While the geological curves are used directly, there are some uncertainties associated with these that are not accounted for. This follows from the expert knowledge that underlies the compilation of the curves, meaning that some variation between them could simply follow from which experts have conducted the geological studies. While there exist more principled methodologies for reconstructing relative sea-level change, which could potentially reduce or be used to assess some of this subjectivity (e.g. Ashe et al. 2019), this is beyond my geological know-how and the scope of this thesis (Deflection 2.4). Furthermore, the procedure for interpolating the trajectory of shoreline displacement to locations between the isobases of the curves was done using inverse distance weighting (IDW). IDW does not account for increased uncertainty as one moves further away from the isobases, and is dependent on how the distance to the isobases is weighed and how many of the isobases are used to inform the interpolation to each location. A host of different interpolation methods exist (e.g. Conolly 2020) which, along with the impact of adjusting the parameter settings for the IDW, would be worthwhile to explore (Potential backing 2.3).

Warrant 3 concerns how the site limits are defined. As was outlined in Section 3.2.1, site limits involves the arbitrary delineation of continuous phenomena represented by the distribution of archaeological artefacts in the landscape. Furthermore, the distribution of artefacts need not represent the entire area making up the activity areas of past inhabitants at a site location. For example the landing area for boats, which presumably has relevance for the location of a site relative to the sea (see also below), can hardly be assumed to be directly reflected in artefact distributions. Deflection 3.2 states that while all of these are valid points, I believe the distances considered means that these dimensions will have limited influence on the final results.

Warrant 4 pertains to the digital terrain model (DTM) that is used when adjusting the sea-level to its position in the Mesolithic. While erosion and modern disturbances has impacted the DTM, this was attempted to be accounted for by using a 10 m resolution DTM that is a down-sampled version of the 1 m version provided by the Norwegian Mapping Authority (Norwegian Mapping Authority 2018), and by manually defining and interpolating the elevation values over especially problematic areas such highways and quarries. While I believe this to have been largely successful, this cannot be guaranteed (Rebuttal 4.3). However, if there are individual cases were this is not true, I believe the overall results to still hold. The future inclusion of a larger sample could also be a way to mitigate such problems.

Warrant 5 states that for the modelling efforts to hold, the precise details of how the distance between site and shoreline was measured is a central component. This pertains both to how the shoreline and the site limits (see Warrant 3) are defined (Rebuttal 5.1), and what methods were used for the measuring of the distances (Rebuttal 5.2). Central aspects here is that the displacement curves used to define the position of the shoreline represent the mean sea-level. For the definition of the site limits, Deflection 3.2 from above is relevant also here, while Potential backing 5.5 suggests that both including an estimate of the tidal range and potentially exploring the definition and uncertainty associated with the delineation of the site limits could be worked into the simulation procedure.

When it comes to the measured distances, the main measure, which also underlies the proposed method for shoreline dating, is the vertical distance between the elevation of the shoreline and the lowest point on the site polygons. In addition to this, measures for the distance between the horizontally closest points on the site and the shoreline, as well as the topographic distance (that is, the distance when accounting for the slope of the terrain) between the sites and the horizontally closest points were also taken. Especially the last measure entails some simplification. Measuring the topographic distance to the horizontally closest points means that this does not necessarily identify the topographically closest points, which is a more computationally expensive operation. Furthermore, identifying the topographically shortest path between these points is also dependent on the choice of least cost path algorithm (e.g. Herzog 2013). Again, however, I believe that the distances considered means that the assumptions and inferential leaps that this warrant requires will have a limited impact on the findings (Deflection 5.3).

The last warrant, Warrant 6, pertains to the treatment of the data following the simulations. This was done by fitting an array of standard models to the univariate distribution of vertical elevation distances between sites and shoreline, and selecting the gamma as the best model by use of the Akaike information criterion (AIC) and Bayesian information criterion (BIC). Given the fairly limited consideration of competing univariate models and the lack of probability estimates for the model parameters, the study can ultimately be considered part of a procedure of modular model construction, where this study represents a first step (e.g. Buck et al. 1996; Gelman et al. 2020).

Finally, the study does not involve any consideration of what factors have caused the distribution of elevation values, which is also reflected by the use of univariate models. In one way, this can therefore be viewed as an instrumental model as the *reason* for the location of the sites has not been considered explicitly. The concern is directed towards prediction not explanation. By combining the present altitude of a site, its likely elevation above the shoreline when it was in use, as informed by the gamma function, and local shoreline displacement curves,

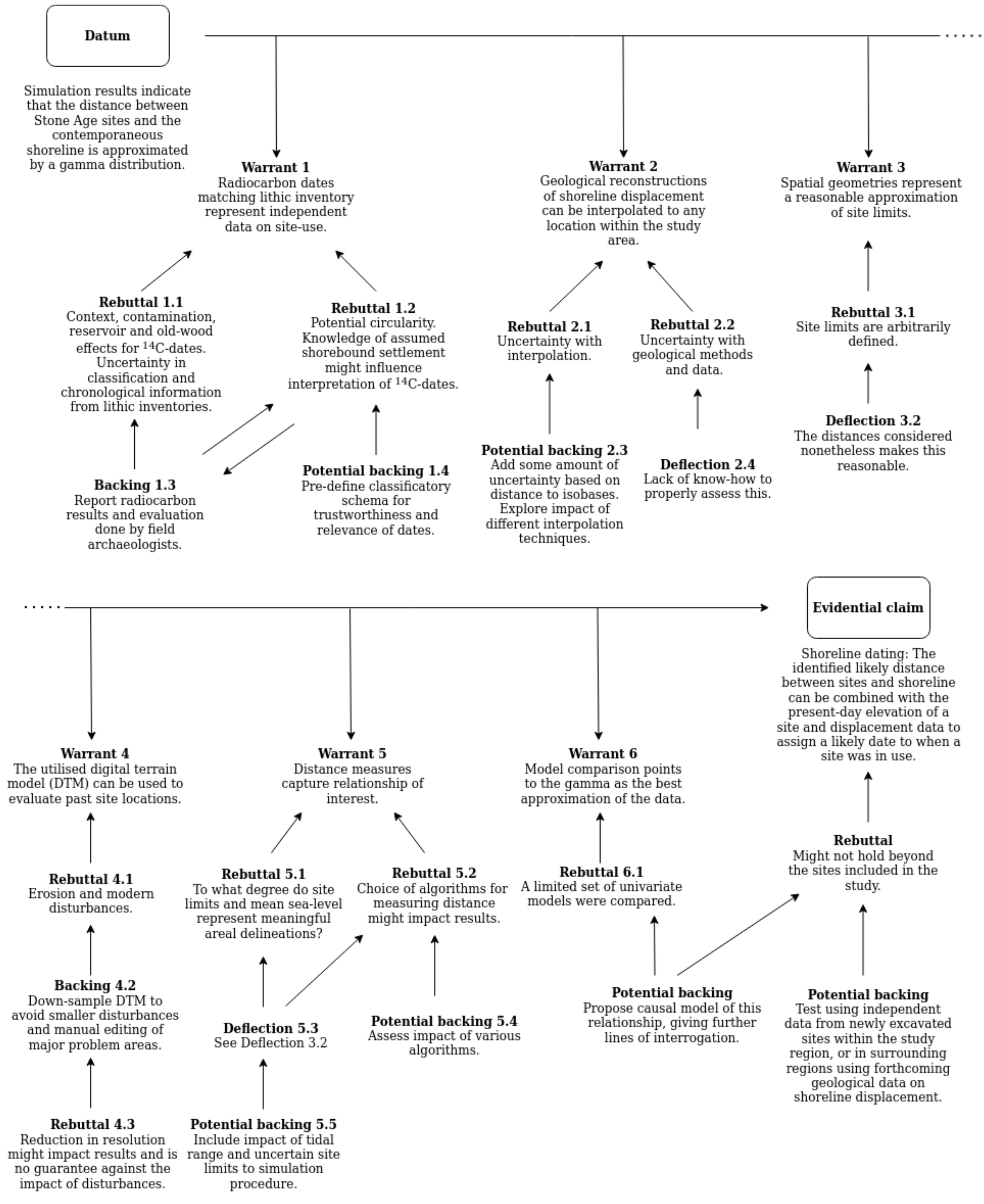


Figure 5.4: Argument schema for Paper 1 and 2.

this model makes it possible to assign a probabilistic absolute shoreline date to coastal sites in the region. While the model and derived method can be viewed as a instrumental dating tool, it is determined by the proclivity for sites to be located on the shoreline. As such, it likely to be tightly integrated with both overarching cultural developments, as well as behaviour at the site level. By extension, the multitude of factors that can have shaped the site-sea relationship on the large and small scale, both temporally and spatially, offers a challenging causal web of possible interacting effects. Having first derived this instrumental model, however, this gives opportunity both to further test its correspondence with other empirical data, and explore and expound underlying theoretical assumptions and implications. To this end, I have constructed a suggestion for a causal model concerning what could be the determining factors for the vertical distance between coastal Mesolithic sites and the shoreline in south-eastern Norway (Figure 5.5).

5.3.1 Causal model for the site-sea relationship

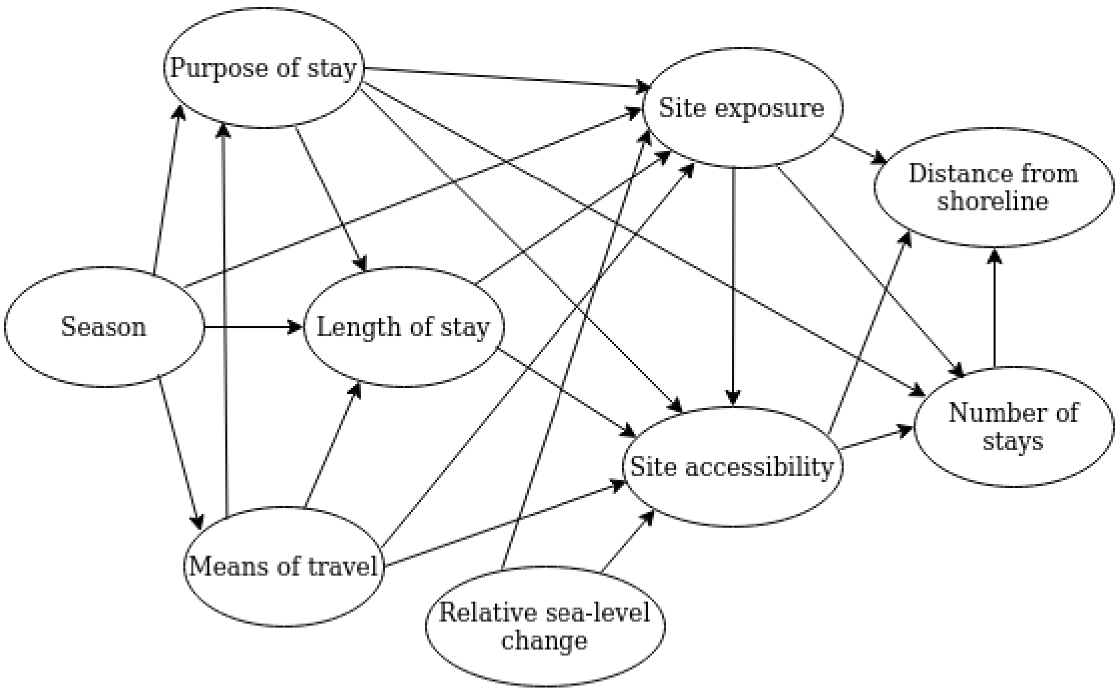


Figure 5.5: Suggested causal model for the drivers behind the relationship between site location and the prehistoric shoreline in Mesolithic south-eastern Norway.

An immediately obvious aspect of the suggested model is that the effect of all variables for the the site-sea relationship is mediated through the variables site exposure, pertaining to the exposure of the location to wind and wave action; site accessibility, concerning access to and from the site; and the number of stays at the site. Consequently, these also represent some of the strongest causal assumptions in the model, as the presence of arrows in causal graphs merely point to a possible causal relationship. The strongest claims of knowledge in a causal graph rather stems from missing arrows (Elwert 2013). Removing arrows can be based on either theory or data, meaning that some of the suggested relationships in the DAG could be proven to be of little to no relevance in future empirical studies or theoretical discussions.

A likely important factor for how exposed and accessible people accepted a site location to be is the purpose of the visit to the site. The purpose of the visit is therefore given a direct effect on exposure and accessibility. For example, is the site meant to be used as a stop to rest and repair tools, to be used as a hunting camp or a location from where to acquire raw materials for tool-production? Is it a base-camp for the entire residential group from where further forays are made, or is it meant to be a meeting place for several groups?

The purpose of the stay is likely also to impact the length of the stay, which in turn might have implications for how close to the shoreline the site is established. A longer stay could for example mean that the site would have to be more withdrawn from the shoreline, so as to make sure storm surges do not reach the site. The length of stay is not given a direct effect on the distance to the shoreline, as sites in the region are interpreted to not having been in used for more than, at most, a few months at a time (e.g Glørstad 2010:80). This means that the shoreline regression would have been negligible within the time-span of any individual stay.

Means of travel is also included in the model. Most travel in the coastal region is assumed to have been done by boat in this period, which means accessibility to the site from the sea is likely to be of concern, as well the ability to safely beach and store the boats. However, what kind of boats that were in use does remain a point of discussion (see e.g. Glørstad 2013 with comments; Schmitt 2013), and could have implications for these dimensions. Furthermore, some travel was also likely done by foot (see e.g. Bjerck et al. 2016; Pettersson and Wikell 2018; Schülke 2023). This could for example be from a base-camp to a site close by for gathering and processing resources, where the need for the carrying capacity offered by boats might not have been necessary. Travel by foot, or by skis or sledge in the winter-timer, for example in connection with the hunting and processing of resting seal that are not disturbed by approaching people, or species of seal that predictably utilise breathing holes in the ice could also be an alternative (see Bjerck et al. 2016). Not having to land boats could presumably have implications for the degree and in what ways a site location could be exposed and accessible.

The season could also have implications for how often one had to establish camp, and possibly led to a reduction of mobility in colder periods (cf. Binford

1990). The season might also influence the kinds of dwelling structures that were necessary to erect, and likely determines the kinds of resources that were exploited, thus potentially impacting the purpose of the stay. The season is also believed to have implications for the degree of wind and wave-action at a location, thus affecting the exposure of the site to the elements, and impacting accessibility. Finally, the season presumably also has implications for the means of travel, for example by reducing the potential use of boats and enabling travel on the ice. Season is therefore given a direct effect on all of these variables.

The full period of time over which a site was is in use could presumably be influenced by relative sea-level change by the determining the frequency of revisits. Depending in part on the topography, relative sea-level change could make a location increasingly less attractive due to a reduced accessibility to and from the site or by impacting its exposure. In periods characterised by a more stable sea-level, on the other hand, a single location would have retained any strategic or beneficial position over a longer time-span, allowing for repeated visits over a longer period. Relative sea-level change is therefore given an indirect effect on the distance to the shoreline, mediated by accessibility, exposure and number of stays. However, these are presumably not the only factors determining the number of times a place could be revisited. Following for example from an investment into more substantial dwelling structures or due to some other factors that might elevate its importance (see e.g. Glørstad 2010:97–102; Schülke 2020), it would seem plausible that such factors could counterbalance, to a degree, the adverse effects of relative sea-level change on the attractiveness of a site location. This is indicated by the the direct effect of purpose of visit on number of visits.

Some variables and nuance that have been left out of the model are worth commenting on. The weather is for example likely to impact many of these factors, but is near, if not entirely impossible to determine archaeologically. Furthermore, the purpose of a stay is here indicated using a single variable, but a stay need not, or perhaps likely did not, have a single purpose. A simple example might be a case where multiple kinds of resources were to be exploited from a site. A possible alternative would be to operationalise these as individual variables, where for example the magnitude of seal-hunting and the gathering of hazelnuts to be done from the site is kept as separate variables. These would in turn likely be determined by factors such as the density of these resources in the landscape, their caloric return, their cost in terms of handling-time and -energy, and the potential prestige associated with hunting or sharing a specific resource (see e.g. Kelly 2013).

Furthermore, the entire picture is also further complicated by other latent variables that are left out of the model. Social structure, overarching mobility patterns, territoriality, group size and composition, as well as religious beliefs could all impact land-use, site-structure and ultimately how sites were positioned relative to the sea. The proposed causal model thus pertains, as was noted above, to what can be termed proximal causes.

Nonetheless, I still believe the model forms a reasonable starting point from where to potentially improve the baseline model, and that it has the potential to reveal some important causal determinants for the site-sea relationship. A central challenge is of course how these factors are to be operationalised and determined archaeologically. The exercise of setting up the causal model is still useful in its own right, if not simply by forcing its author to think through and concretise what elements they believe are important and how these are related, but it also forms a framework that dictates how these variables would have to be handled analytically.

A central challenge for the proposed model is thus how the different variables can be measured. For example, determining the season for when a site was in use is possibly an insurmountable challenge in many cases, but some avenues for investigation exist. The most immediate line of evidence is drawing on faunal and vegetational material. Depending on what resources were exploited, this could make it possible to discern in what season the sites were in use (e.g. Boethius et al. 2020; Mikkelsen 1978). Furthermore, Solheim and Persson (2016) speculated whether what they identified as a predominance of fish remains on sites located in outer coastal areas, as opposed to terrestrial faunal material at sites in inner coastal areas, could reflect seasonal movement patterns (see also Bergsvik et al. 2020). As bone is typically poorly preserved in the acidic Norwegian soils, this is a challenging line of evidence to draw on, but if this could be shown to consistently correspond to other site features such as their location, this could possibly be extended to sites where bone is not preserved.

Similarly challenging is determining the means of travel. While boats can be reasonably be assumed to have been the main means of transportation throughout the Mesolithic in the coastal region, some controversy surrounds what kinds of boats were in use (e.g. Glørstad 2013, with comments), and it has been suggested that sledges and skis could have been used in inland areas (see Sørensen et al. 2013). Although the relevance of this variable is therefore not certain, and these suggestions remain speculative, one line of reasoning could again be to examine the topographic location of the site in an attempt to reveal if this can be found to be related to the means by which the sites were reached.

When it comes to measuring the length of stay, it was suggested in the third paper of this thesis (Roalkvam 2022), as presented in more detail below, that aspects of the lithic inventories reflect the duration of stays at the sites under study. Assessing the distance between site and shoreline when accounting for these measures could therefore offer a way forward in this regard. The length and purpose of the stays are likely to be tightly integrated, but the analysis of lithic inventories offer a clear possibility for approaching these issues.

Exposure is one of the variables in the suggested causal models where a range of analytical avenues exist. The exposure of Mesolithic sites was investigated in Roalkvam (2020) by using viewshed analysis to estimate visibility, and the estimation of wind-fetch to measure exposure to wave-action. A third potential way to handle exposure could be to devise a method for estimating the distance from the site to the outer-most coastal feature to evaluate their location within the wider landscape (see Section 2.2.1). Although all of these measures have seen limited or no previous application in Norwegian archaeology, they offer clear ways forward with which to investigate these issues.

Accessibility is another challenging variable to operationalise that has not been explored much in the literature. Good landing places for boats are often pointed to in excavation reports and in the literature. Common defining features of this appears to be a gentle slope towards the prehistoric shoreline, which can readily be explored in a geographical information system, as well as the degree to which the surroundings of a site forms a natural harbour by being less exposed to winds and wave-action (e.g. Bjerck 1990; Nummedal 1923; Pettersson and Wikell 2018). Drawing on the methods suggested for estimating the exposure a site, its accessibility could therefore also conceivably be measured.

While multiple occupational phases as suggested by ^{14}C-dates were included in the analysis for Paper 3, the number of stays at the sites was not treated explicitly when deriving the method for shoreline dating. Both radiocarbon dates and lithic inventories can provide information on the number of visits (e.g. Åstveit and Tøssebro 2023), and a possible approach could be to stratify the measure of distances from site to shoreline by inferred phases of occupation in future studies.

As it stands the most readily operationalised explanatory variables of the model is therefore the duration of the stays at the site, their exposure to surrounding landscape – and potentially the accessibility to the sites and the number of occupational phases. To conclude, this exercise has demonstrated some of the value of suggesting an explicit causal model, and has laid out some potential avenues for further interrogating the issue of the relationship between coastal Mesolithic sites and the contemporaneous shoreline.

5.4 Modelling the technological expediency of Mesolithic assemblages

The third paper of this thesis (Roalkvam 2022) was aimed at exploring methods for handling lithic assemblages associated with the large number of excavated Mesolithic sites in the region, which can range in size from a few hundred to several thousands artefacts. The 55 sites chosen for analysis were excavated as part of four large excavation projects undertaken by the Museum of Cultural History in the last two decades, and were located within a constrained geographical area. This means that the excavations were carried out using similar excavation methods and that the classification of the artefact inventories followed similar guidelines. This choice of sample was aimed at reducing the amount of variation in the assemblages that could follow simply from investigatory and classificatory differences, as well as from variable access to raw materials when the sites were in use. The analysis focused on two analytical avenues. The first of these was to evaluate the chronological development in the occurrence of artefact categories over time, which in large part appears to coincide with previous suggestions in the literature. The second line of investigation was aimed at exploring methods for tracking variation in mobility patterns based on the composition of lithic inventories, which is the part of the analysis that is in focus here.

In terms of chronological fixing of the occupation of the sites, this was based either on radiocarbon dates or shoreline dates in combination with typological indicators. As this study was undertaken before Paper 1 and 2, the newly proposed method for shoreline dating had not yet been developed. This means that the dates informed by shoreline displacement and typological indicators were accepted as they are given in the original excavation reports. In addition to this, only radiocarbon dates seen as relevant for the occupation of the sites in the reports were considered.

The evidential claim of the paper is that the forager–collector continuum, as outlined in Section 3.3.2, is captured by variables taken from the Whole Assemblage Behavioural Indicators (WABI, see Clark and Barton 2017). This involves the assumption that the abundance of available resources and knowledge of their sources impacts the degree of retouch that has been done on the lithics constituting the assemblages, where retouch is taken to represent efforts to extend the use-life of lithics by rejuvenating edges and re-purposing tools. Following this logic, higher mobility will lead to a greater necessity to conserve lithics in anticipation of more uncertain and less predictable circumstances. Lower degree of mobility, on the other hand, should affect the organisation of lithic technology by leading to more predictable surroundings, distribution of resources and what tasks that will have to be performed. This is assumed to lead to a reduced necessity for conservation and re-purposing of lithics. The different forms of technological organisation that is to result from these situations is denoted by the terms curation and expedience, which, following from their dependence on on mobility patterns, are to reflect the forager–collector continuum. The central empirical correlates of technological curation is high degrees of retouch and low overall density of lithics, with the reverse being defining for technological expediency.

The analysis undertaken for the paper was exploratory, meaning that a range of variables in the assemblages that have previously been associated with mobility patterns were included in the undertaken principal components analysis to assess their ability to explain the variation in the data. The findings confirmed that the proportion of non-flint material in the assemblages increases through the Mesoltihic, as has been noted by numerous authors over the years (e.g. Reitan 2022; Solheim 2017b), and which has been argued to be an indication of decrease in residential mobility through the Mesolithic of south-eastern Norway (Glørstad 2010:181; Jaksland 2001:112). Furthermore, this development conforms with the expectations of the WABI by showing an overall decrease in the proportion of secondarily worked lithics and an increase in the volumetric density of lithics on the sites over time.

To further explore the nature of this development, while also accounting for the temporal uncertainty associated with the dating of the sites, the two WABI variables were combined into a 'curation index'. This was done by min-max normalisation, adjusting the variables to take on values between 0 and 1. The volumetric density of lithics was then made negative, as higher values is to indicate a lower degree of curation, and the mean was then taken for the two variables for each site to find their value on the curation index. A simulation was then performed to account for the temporal uncertainty associated with the developments in this curation index over time. For each simulation run, the date of a site was drawn from their associated date ranges, either uniformly in the case where the site was dated by reference to shoreline displacement and typology, or, where these were available, by drawing the year weighted by the sum of the posterior density estimates of radiocarbon dates. For each simulation run, a locally estimated scatterplot smoothing (LOESS) curve was fit to the data to capture the overall developments in the curation index. The average LOESS curve from 1000 simulation runs is given in Figure 5.1B.

The necessary warrants underlying the study are presented in the argument schema in Figure 5.6. The first warrant pertains to the issue of whether the artefact inventories have been consistently categorised across excavation reports. The support for this can initially be found in the sample of sites that was chosen for the study, which was aimed at being likely to have artefact inventories that were categorised using similar methods. To add to this, the key variables of the WABI, namely proportion of secondarily worked lithics and volumetric density of lithics, are both variables that have had the same definition for decades (cf. Helskog et al. 1976). Consequently, while the sample itself makes this rebuttal likely to be of less concern, part of the value of the WABI is that these variables lend themselves well to studies of legacy data where more modern classificatory schemas have not been used (Backing 1.3, Clark and Barton 2017). However, some ancillary expectation of the WABI were not found to correspond to the suggested developments. This

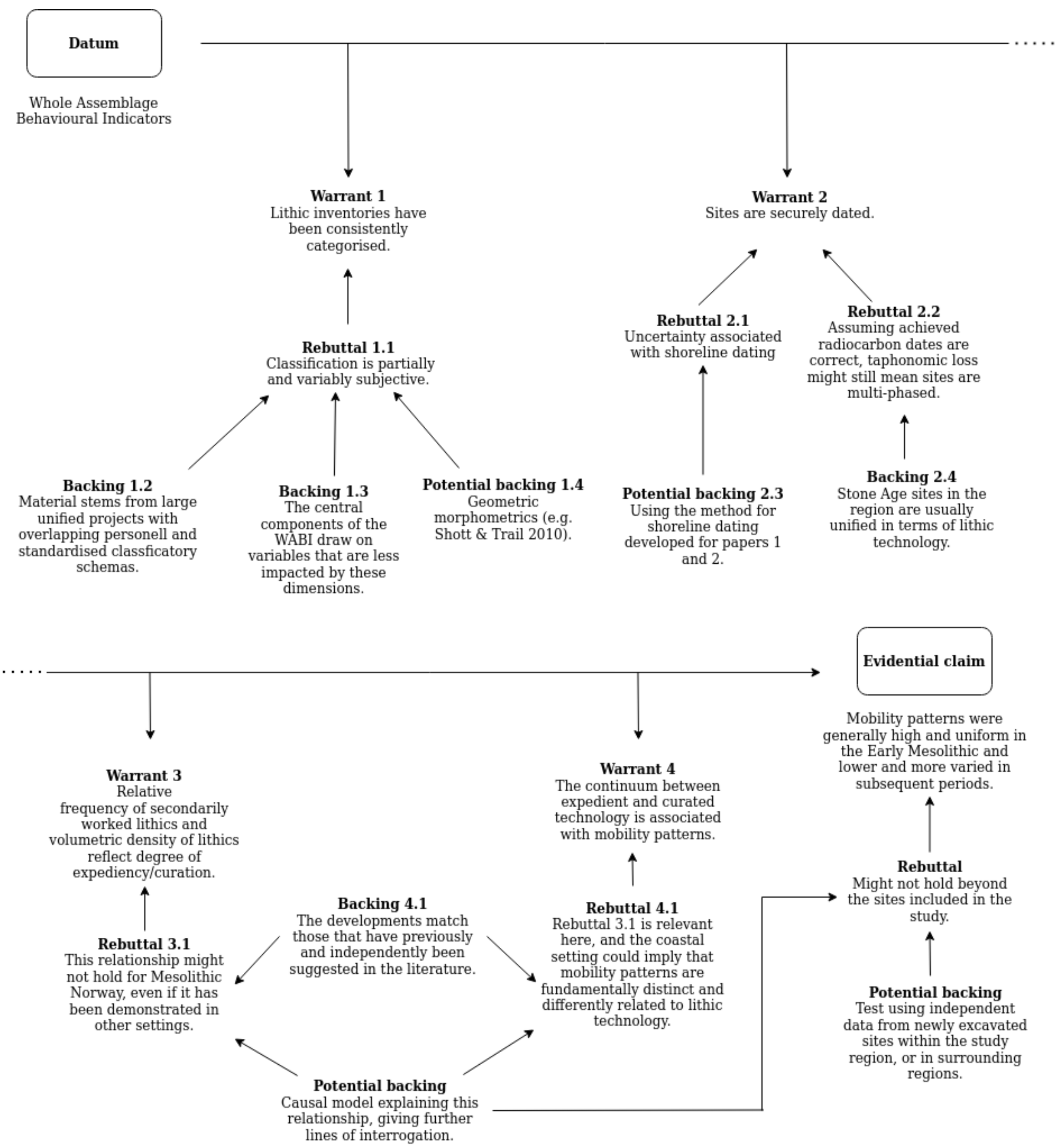


Figure 5.6: Argument schema for Paper 3.

especially pertains to the role of cores. One expectation of the WABI is that unexhausted cores is likely to be more frequent in assemblages characterised by a lower degree of mobility, but no clear chronological patterning could be identified in the frequency of cores in the assemblages. However, this could be related to the fact that these are often not classified beyond being categorised as cores, and so a more in-depth analysis might reveal different patterns related to dimensions such as the exhaustion of the cores. While the analysis of cores need not employ this methodology, this point can be related to Potential backing 1.4 in the argument schema, where a more principled analysis of the artefact inventories by the use of geometric morphometric is suggested (see e.g. Matzig et al. 2021; Shott and Trail 2010).

Warrant 2 concerns the chronological control for the accumulation of the lithic assemblages. 17 of the 55 sites were associated with radiocarbon dates which were seen as relevant to the occupation of the sites in the original reports. Multiple dates from a single site were then treated by use of the Boundary and Sum functions in OxCal, and so the same points as those discussed for radiocarbon dates in relation to Paper 1 in Section 5.3 are also relevant here. More critical is the fact that as Paper 3 was written before Paper 1 and 2, the newly developed method for shoreline dating was not applied. Instead, the shoreline dates were taken directly from the reports. In Paper 1 I found that previous applications of shoreline dating generally corresponded with the start dates of the ones achieved with the newly proposed method, but previous application have tended to overestimate the precision of the dates (Roalkvam 2023a:11–15). This can in part follow from the fact that the excavation reports also draw on typological information and not only shoreline dating, thus constraining the achieved date. However, this has always been done in an informal manner and so it is difficult to assess the degree to which the precision achieved in the reports can be justified (Rebuttal 2.1). The chronological control could therefore be somewhat exaggerated for Paper 3, and a clear point of improvement would be to undertake the study using the new method for shoreline dating (Potential backing 2.3).

Warrant 3 and 4 can be treated in unison here, as they concern whether the curated–expedient continuum is meaningfully captured by the variables of the WABI, and whether this in turn reflects the forager–collector continuum as originally devised by Binford (1980). As is indicated by the title of the paper *Exploring the composition of lithic assemblages in Mesolithic south-eastern Norway*, the paper is explicitly exploratory. This means that it was aimed at identifying empirical patterns and suggest some potential explanations for their occurrence. The study thus decidedly entailed *post hoc* accommodative argumentation (see Section 4.1), as the explanations were construed following the identification of the empirical patterns. These patterns correspond to those that could be expected from the main components of the WABI, with previous suggestions for the development of mobility patterns through the Mesolithic of south-eastern Norway, and with the corresponding increased use of non-flint material through the period (Backing 4.1). The relevance of the WABI for tracking mobility patterns based on lithic assemblages has been explored and substantiated over a range of different contexts in Eurasia – ranging in temporal coverage from the Pleistocene to the Holocene, and by drawing on assemblages associated with both Neanderthals and anatomically modern humans (e.g. Barton et al. 2013, 2018; Clark and Barton 2017; Riel-Salvatore et al. 2008).

However, as a first attempt at employing these measures in the context of Mesolithic Scandinavia, and, as was noted in Section 3.3.2, following from the coastal setting that might have implications for the applicability of the collector–forager continuum, both the reliability of Warrant 3 and 4, and, by extension, the the main evidential claim of the paper should be explored and tested in a range of ways (Rebuttal 3.1 and 4.1). First, given the explorative and accommodative analytical framework, additional testing of the framework using independent data would be fruitful both to assess the strength of the evidential claim, and has the potential to reveal nuances that were not captured in the study undertaken for Paper 3. Furthermore, given the developments in mobility patterns that this framework is believed to capture, drawing on other variables that are believed to be related to these developments should also be explored. A fruitful first step to achieve this is to set up a causal model, a suggestion for which is presented in Figure 5.7.

5.4.1 Causal model for the expediency of lithic assemblages

The causal model that underlies the relationship between lithic inventories and residential mobility is fairly straightforward in that it posits that higher residential mobility leads to a higher degree of expedient technological organisation. This follows indirectly from the assumption that a reduction in mobility leads to a better predictability of raw material availability and allows for its accumulation if sites are occupied for a longer duration. With increased occupational duration, the tasks that will have to be carried out are also believed to more predictable than in a situation of high mobility, where changing and more unpredictable circumstances will lead to a more curated technology. In the model, residential mobility is therefore given a direct effect on all the variables underlying the curated–expedient continuum. This relationship is effectively an instantiation of that which has been proposed by Barton and collegues in other context (e.g. Barton and Riel-Salvatore 2014; Clark and Barton 2017), where properties of the lithic assemblage functions as indicator variables for the underlying causal drivers.

An addition to the model that is more specific to the Norwegian Mesolithic follows from the role of non-flint material. It was found in Paper 3 that an increase in the use of non-flint material occurs over time. As mentioned above, it has previously been suggested that this reflects an increased familiarity with local surroundings, and that this is related to a decrease of residential mobility. In the paper it was found that the overall development in the curation index was robust to removing non-flint material from the data set. However, as the use of non-flint material is generally associated with a higher abundance of debitage per secondarily worked artefact, this procedure did markedly increase the curation values for some individual sites. The effect of non-flint material can therefore potentially be more significant and skew the measure in other contexts.

An important assumption concerning the role of non-flint material in the suggested causal model is that there is no direct effect between choice of raw material and technological expediency. The assumption is thus that raw material only impacts the empirical indicator variables for technological expediency without directly impacting the fundamental technological strategy itself. However, it is possibly premature to remove this arrow of effect, as it is a proposition that would benefit from further substantiation, including an assessment of the degree to which choice of material might impact raw material predictability. Furthermore, excavations in areas such as Aust-Agder, located south of the study area of Paper 3, have found that quartz is often a more dominating part of the assemblages in this region (e.g. Reitan and Sundström 2018). Thus, while the overall developments were robust to the effect of excluding non-flint material for the sample of assemblages considered for Paper 3, it is not clear that this relationship necessarily holds in areas with a different availability of various raw materials. Consequently, the question of the spatial stationarity of the relationship between non-flint material and expediency is relevant, irrespective of whether this is thought to be of direct causal relevance for technological organisation or for the adjustment of its indicator variables.

Finally, while the sample of sites chosen for Paper 3 was aimed at reducing the confounding effects of investigatory and classificatory differences that might exist between excavations, it is possible that with an extension of the study to include a larger sample, nodes representing such effects should be included in the causal model.

In the exploratory setting of Paper 3, the relevance of the WABI was mainly arrived at based on their correspondence with overall developments in mobility patterns and use of non-flint material that has previously been proposed in the literature. However, a proper evaluation of the causal model presented in Figure 5.7, and a clarification of the potential role of the curated–expedient continuum for tracking mobility patterns will depend on comparing it with other, properly operationalised variables that have been suggested to be of relevance to the same developments. One way forward in this regard is represented by the the findings of the fourth paper of this thesis.

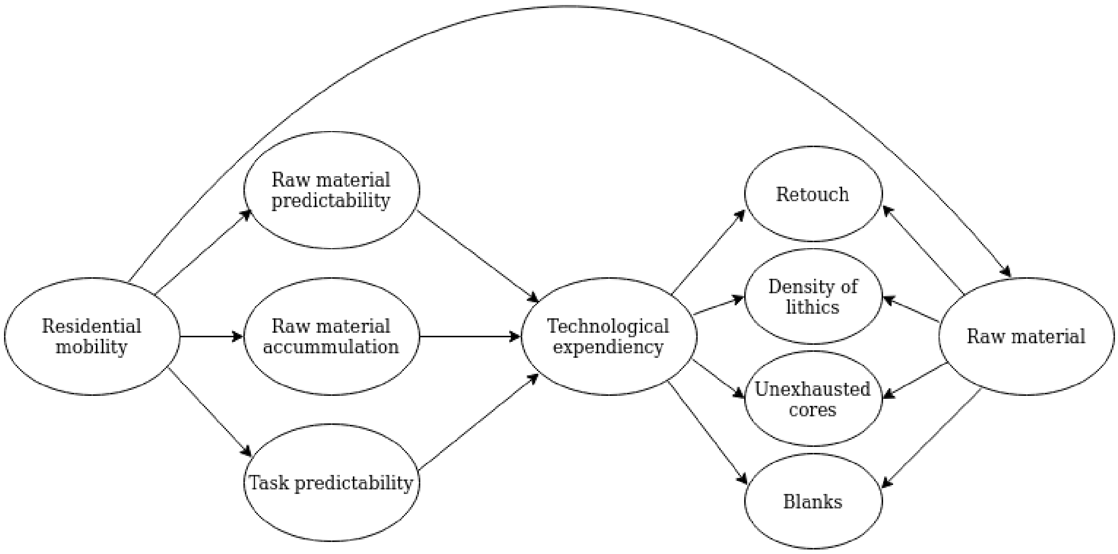


Figure 5.7: Suggested causal model for the drivers behind the relationship between mobility patterns and the composition of lithic inventories.

5.5 Modelling demographic developments through the Mesolithic

The fourth and final paper of the thesis is written in collaboration with Steinar Solheim and has been uploaded as a pre-print and submitted to PCI Archaeology for open peer review (https://archaeo.peercommunityin.org/PCIArchaeology/), before it is to be submitted to a journal for publication. The paper contrasts two proxies that have often been drawn on to model relative population density in Fennoscandia, namely radiocarbon and shoreline dates (e.g. Solheim and Persson 2018; Tallavaara and Pesonen 2020). These are analysed by way of summed probability distribution of radiocarbon dates (RSPD), and, drawing on Paper 1 and 2, the summed probability distribution of shoreline dates (SSPD) from within the study area.

The study was based 310 ^{14}C-dates. The procedure of summing these start by combining multiple dates from a single site that fall within 200 ^{14}C-years of each other to account for cases were the investigatory context or research interests might have impacted the number of undertaken radiocarbon dates, thus potentially biasing the frequency of dates (see e.g. Crema 2022). This procedure therefore effectively reduces the sample of dates by weighting these site-phases equally in subsequent analysis. Undertaking this procedure reduced the effective sample from 310 dates to 134 site-phases for the final RSPD. To account for the possible fluctuations in the RSPD that could follow from sampling error or wiggles in the calibration curve, an exponential, logistic and uniform model were then fit to the RSPD and the distribution of dates that could be expected if the development followed these models were simulated 10,000 times to achieve a critical envelope of expected values given each null model (for details, see e.g. Crema 2022; Crema and Bevan 2021; Shennan et al. 2013; Timpson et al. 2014; Timpson et al. 2021). Of these models, the logistic development was found to be the best alternative, and the simulation procedure confirmed that the available data could be expected under this model.

The same procedure was then adapted to the sample of shoreline dated sites, consisting of 820 surveyed sites and 101 excavated and previously shoreline dated sites. This gave a total of 921 sites for the final SSPD. Given that the dating procedure does not treat the possibility of multiple site-phases explicitly, the SSPD is the sum of performing a single shoreline date for each site. The same three base models as those used for the RSPD were then fit to the SSPD. In the employed method for shoreline dating, the local trajectory of relative sea-level change effectively fulfils the same purpose as the calibration curve does in the handling of radiocarbon dates. Consequently, the dates that were simulated to characterise the expected development under each null model for the SSPD was here based on the distribution of observed sites in the study region and the local trajectory of shoreline displacement associated with these site locations. All standard models could be rejected for the SSPD, with the exponential model being identified as the best alternative. This indicates an overall decrease in sites over time, but given that the model could be rejected and given the deviations from the simulation envelope evident in Figure 5.1D, this does not adequately capture the distribution of the data.

As can be seen from Figure 5.1C and D, the temporal distribution of the proxies thus follow different trajectories. Given the overall reduction in mobility that has been argued to occur through the Mesolithic (see Chapter 2), we suggested that the mismatch could reflect a case where the frequency of shoreline dated sites is more heavily influenced by mobility patters than population density, and that the reverse is true for the RSPD. However, as the main focus of the paper was to establish a method for handling and assessing the summed probability of shoreline dates, these discrepancies were given a purely narrative treatment in the paper. This is reflected in the argument schema in Figure 5.8, which pertains both to the methods used for assembling the RSPD and SSPD, and the potential substantive implications these might have.

The first warrant in the schema pertains to the included sample of surveyed sites, which is taken from the national heritage data base Askeladden, maintained by the Norwegian Directorate for Cultural Heritage (Norwegian Directorate for Cultural Heritage 2018). As is pointed out in Rebuttal 1.1, these records and associated spatial geometries are of widely varying quality and the site records were originally created for the purposes of cultural resource management – the reliability of any individual record for research purposes can therefore not be readily assumed. To accommodate this, we employed a scoring system going from 1–6, pertaining to the quality of the site records and the degree to which the spatial geometries provided in the database could reasonably be assumed to reflect the position and spatial extent of the sites (Backing 1.2). This system was originally used in Roalkvam (2020). While we employed a single cut-off for the quality of the site records when determining what sites to include in the study, it would also be possible to explore the implications of adjusting this exclusion criteria to further evaluate the robustness of any observed patterns.

The second warrant concerns the degree to which shoreline dating is a reliable method for dating coastal Stone Age sites. While its application for Paper 4 extends beyond the original sample used to derive the method (Rebuttal 2.1), the shoreline dated sites for Paper 4 are all taken from within the same study region as the one used in Paper 1, giving some support for an assumption that it holds for the analysed sites (Backing 2.2). The reliability of the application of shoreline dating for the purposes of Paper 4 is nonetheless premised on the argument schema for Paper 1 and 2, and would therefore clearly benefit from any additional evidential support that would follow from handling the rebuttals related to these papers (Potential backing 2.3).

The third necessary warrant for the comparison between the SSPD and RSPD to be meaningful is that the radiocarbon dates included in the RSPD stems from reliable anthropogenic contexts. The radiocarbon data is provided in the repositories for the paper, where the context has been noted, also making it possible for others to assess this. However, as for Paper 1, the use of a predefined auditing system for evaluating the reliability of the dates would be beneficial, following for example Pettitt et al. (2003; implemented by e.g. Riede and Edinborough 2012).

The fourth warrant concerns the treatment of the two SPDs once these had been assembled. This was done using standard approaches for the RSPD (see e.g. Crema and Bevan 2021; Timpson et al. 2014), with the exception of using maximum likelihood estimation for fitting the three compared null models to the data, and for comparing their performance using the Bayesian information criterion. This was done using the recently developed methodology of Timpson et al. (2021; see also Crema 2022; Crema and Shoda 2021). For the SSPD, a bespoke methodology had to be developed to account for idiosyncrasies of the dating method when simulating the distribution of dates that could be expected under the three null models, but this draws heavily on the framework used with ^{14}C-dates. The main adjustment involves accounting for the distribution of the sites within the study area, relative to the direction of the isobases. Given that the shoreline displacement varies along a south-west/north-east gradient (see Section 2.1.2), the distribution of sites will have implications for the frequency of sites that could be expected under each null model. By accounting for the distribution of sites, the variable relative sea-level change in the study area is reflected in the achieved simulation envelopes.

Although adjustments to the algorithms used for shoreline dating and for simulating the critical envelopes could follow from future developments of the method of shoreline dating, the main rebuttal to Warrant 4 follows from the fact that all three standard models could be rejected as explaining the data in the SSPD. The simulation envelope associated with a rejected null model only addresses the failure of the data to accord with the null model of choice, and, following from the use of a 95% critical envelope, 5% of these deviations could be expected to occur by chance without it being possible to ascertain which 5% this pertains to. The deviations do therefore not give any statistical justification for interpreting the deviations themselves, and only represent deviations of a potentially meaningful nature. Put differently, the model does not explain the data, and the deviations merely indicates temporal regions where the data deviate from an erroneous model. Consequently, there is a danger of over-interpretation and placing too much analytical weight on these deviations, which has been argued to often be the case (Timpson et al. 2021).

The fifth warrant pertains to the degree to which the frequency of radiocarbon dates reflect population numbers. This is based on the fundamental premise that more dateable material from a given time-interval is a reflection of more people responsible for depositing this material. This is known as the dates-as-data approach, as proposed by Rick (1987). Some issues that have been argued to potentially confound this premise is taphonomic loss (e.g. Surovell et al. 2009), sampling error (Timpson et al. 2014), different cultural or economical practices that could result in variable output of dateable material irrespective of population density (e.g. Freeman et al. 2018), and investigatory biases that could impact the number of radiocarbon dates that are carried out for specific contexts or time-intervals (see e.g. Crema 2022 and Section 3.3.4). Some methodological solutions have been presented to account for such biases, such as adjustments to account for taphonomic loss, sample selection that is likely to derive from populations with similar economic and technological systems, and methods for weighting multiple radiocarbon dates from the same context to reduce investigatory bias. However, without independent evidence for the connection between RSPDs and population dynamics for a given context, an inferential leap is nonetheless necessary (Rebuttal 5.2). An approach that many authors therefore agree can make such inferences more robust is to compare the agreement between multiple population proxies (e.g. French et al. 2021; Palmisano et al. 2017), which is the fundamental motivation for undertaking the comparison between the frequency of radiocarbon and shoreline dates in Paper 4.

As a consequence of the mismatch between the two proxies, the sixth warrant pertains to the degree to which this discrepancy can be accounted for by mobility patterns that more heavily impacts the SSPD. The earliest part of the Mesolithic is in the SSPD indicated to be associated with a higher number of sites, but lacks a signal in the RSPD, leading to the hypothesis that this is the result of colonising groups characterised by low population numbers and high mobility. The subsequent drop in the SSPD was then seen in relation to migratory events from the east, believed to lead to a reduction in residential mobility and reduction in the number of sites. The conclusion of this drop corresponds to the first signal in the RSPD, which rapidly grows before it plateaus in the first centuries after 8000 BCE. This plateau also corresponds to a positive deviation in the SSPD, which we in combination suggest is an indication of a population increase that is reflected in both proxies. As the logistic model fit to the RSPD then remains stable for the remainder of the period, one possibility is that the subsequent fluctuations in the SSPD follows from variation in mobility patterns that have no bearing on population density. However, it is also possible that the relatively small sample of radiocarbon dates hides fluctuations that match those in the later parts of the SSPD. It is thus an open question if the degree to which the proxies respond to and reflect population density and mobility patterns is stable throughout the Mesolithic, and if other variables might impact these (Rebuttal 6.2). Unpacking this will not least depend on also including independent measures for mobility patterns (Potential backing 5.3), but will benefit from drawing on multiple interrelated variables explicated by means of a causal graph (Potential backing 6.3).

5.5.1 Causal model for demographic developments

The fourth paper can thus be said to mainly provide a methodological framework for assembling and assessing the summed probability distribution of shoreline dated sites. With a comparison with the RSPD, this led to the development of some hypotheses pertaining to the relationship between the variables. This is presented as a DAG in Figure 5.9. It is important to underscore that given the narratively fashioned and highly speculative explanation for the patterns and divergent relationship between the proxies, the DAG presented here extends far beyond that which has been substantiated empirically and remains fairly unspecified in terms of the processes underlying it. Exploring and adjudicating between

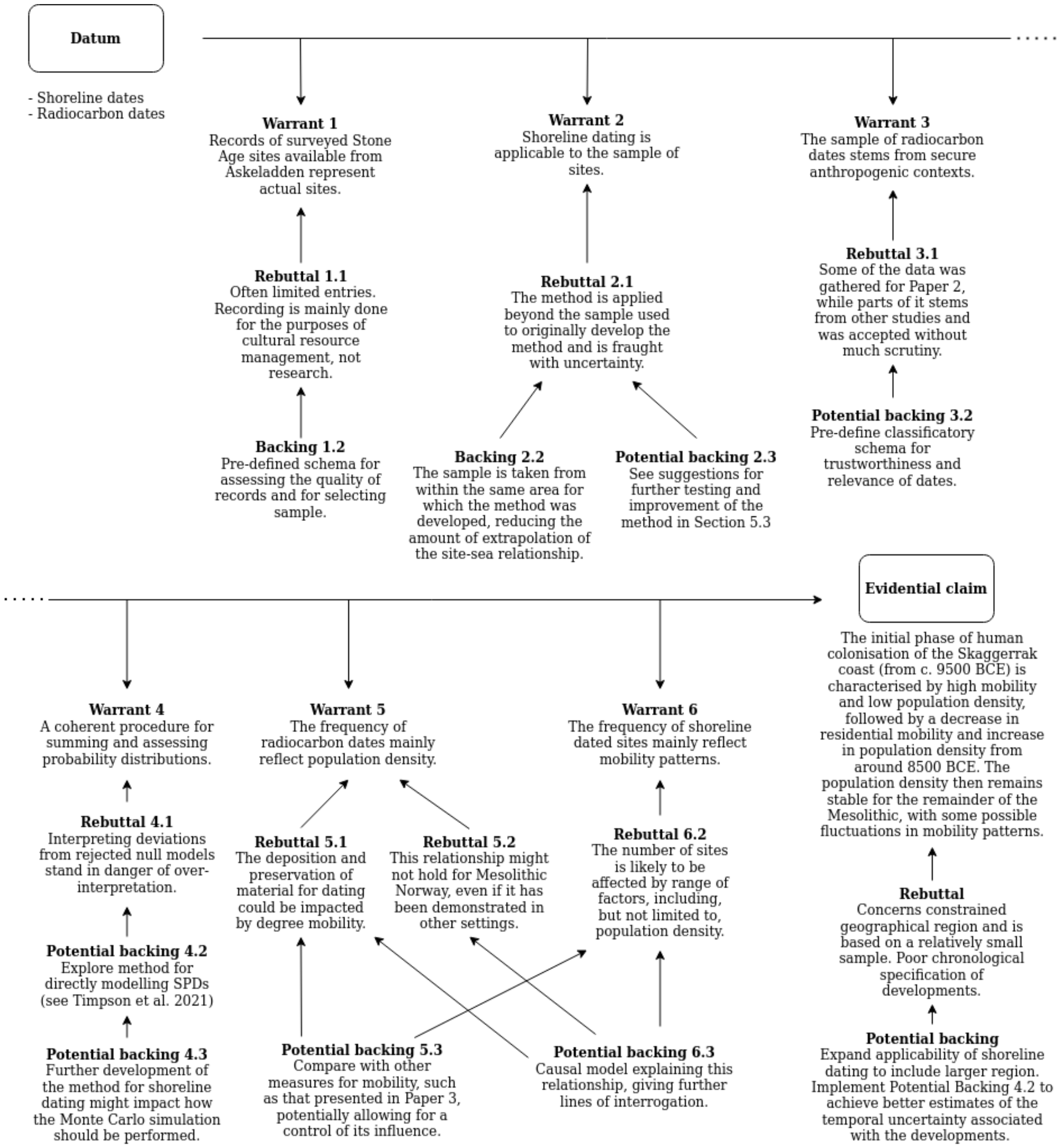


Figure 5.8: Argument schema for Paper 4.

potential explanations will ultimately depend on drawing on the other variables in the DAG, and that adequate temporal and spatial resolution allows these to be meaningfully compared and contrasted.

The most proximal causes to the frequency of ^{14}C-dates and frequency of shoreline dated sites is suggested to be population numbers, mobility patterns and investigatory factors. Not indicated in the DAG is that it is hypothesised that the frequency of shoreline dated sites is more heavily influenced by mobility patterns than population numbers. Furthermore, while the influence of mobility on the frequency of radiocarbon dates is thought to be small compared to population numbers, the absence of radiocarbon dates from the earliest parts of the Mesolithic, where we know people were present, would indicate that this is a non-zero effect. The node representing investigatory factors, on the other hand, is meant to pertain both to the range of ascertainment biases that are frequently discussed in the literature on RSPDs (e.g. Crema 2022; Rick 1987; Shennan et al. 2013) and those that might influence the frequency of shoreline dated sites that can be assigned certain time intervals. The binning of ^{14}C-dates, as mentioned above, is one way to try to reduce the influence of such ascertainment biases for the number of radiocarbon dates. However, as Crema (2022) has noted, this does lead to a case where focus is slightly shifted towards counts of occupational events on the sites, rather than purely the number of radiocarbon dates. This shift in what is being counted could have implications for what underlying processes the analysis can unveil. When it comes to the SSPD, which is based on the shoreline dating of surveyed and excavated sites, a pertinent question would be if certain elevations have been more intensely surveyed than others, which could bias the SSPD. Evaluations done by Persson (2014) and Solheim (2017b) found that different elevations were generally surveyed with equal intensity (Solheim and Persson 2018:340). However, as these only pertain to two fairly recent survey projects, a more principled evaluation of the degree to which this has been the case, also for earlier projects, would be beneficial to ascertain the degree to which such biases might influence any findings. The same also extends to whether certain elevations have been more intensely targeted by the expansion of infrastructure, which is the main determinant for where archaeological surveys are undertaken.

The purely narrative treatment of mobility patterns in the paper focused on the degree of residential mobility, which, following from Paper 3 and the suggestion of previous research, was argued to be reduced around 8500–8300 BCE. This has been suggested to follow from migratory events involving an influx of people from the east around the transition to the Middle Mesolithic c. 8300 BCE (see Section 2.2.2). Following this, if the results from Paper 3 are assumed to be trustworthy and applicable to the study area for Paper 4, this would indicate that degree of residential mobility then remains stable for the remainder of the Mesolithic. The fluctuations in the SSPD following the transition to the 7th millennium BCE could therefore potentially be related to other aspects of mobility, such as seasonal and territorial movement between inland and coastal areas (see Section 2.2.3).

Another central element in the DAG is the direction of the effect indicated between mobility patterns and population density. This follows from the empirical patterns that were indicated by the data. The dramatic drop in the SSPD appears to be followed by the first signal and increase in the RSPD, which culminates with a corresponding positive deviation in the SSPD. These developments are hypothesised to follow from the confounding effects of migratory events that lead to a reduction in residential mobility and increased population density. Given that the logistic model fit to the RSPD is stable following this, despite fluctuations in the SSPD, there are as of yet no direct empirical grounds on which to claim that there is any causal effect between the variables following this initial phase. A negative deviation in the RSPD from the logistic model around 6400 BCE does correspond to a negative deviation in the SSPD, but the deviation in the RSPD has to be disregarded given the failure to reject the logistic model – at least given the present data and modelling efforts. A potential, albeit highly speculative suggestion was nonetheless forwarded with the suggestion that this deviation could follow from an increase in inland utilisation at the expense of the coastal areas in this period (see also Section 2.2). However, with an increased empirical resolution and size of the employed data set it is likely that the relationship between mobility patterns and demographic developments is best represented by series of nodes in the DAG, reflecting the likely complex web of feedback effects that operate between residential mobility and population density (e.g. Jørgensen 2020b; Kelly 2013:209–213). Thus, the current set-up of the DAG is likely to miss reverse causality and unobserved confounding effects (e.g. Rohrer et al. 2022).

The suggested DAG also includes a node for environmental conditions. No direct consideration of this was made in the paper and the node is likely to represent a more complex web of interacting effects with factors such as oceanographic developments, precipitation and temperature changes having frequently been demonstrated to be of relevance for demographic developments in past hunter-gatherer populations (e.g. Hoebe et al. 2023; Jørgensen 2020a; Lundström 2023; Ordonez and Riede 2022). The rate of relative sea-level change is included as its own variable in the DAG, as it was suggested in the paper that the rate of sea-level change might induce changes to settlement patterns without having any direct influence on population numbers. The rate of relative sea-level change can be directly derived from the displacement curves in use and can therefore readily be drawn on in future studies. Albeit somewhat limited, there do exist data for variation in other environmental dimensions through the Mesolithic of south-eastern Norway (see Solheim et al. 2020 with further references), and data for variation in sea-surface temperature is also available for the the mid- to late Holocene of Skaggerrak (Polovodova Asteman et al. 2018). In sum, these offer some potential potential avenues for exploring these issues further. Furthermore, if the framework from Paper 3 can be expanded upon and given a more solid evidential foundation, as indicated in Potential backing 5.3 in Figure 5.8, this can be potentially be used to assess the SPDs while controlling for variation in mobility patterns.

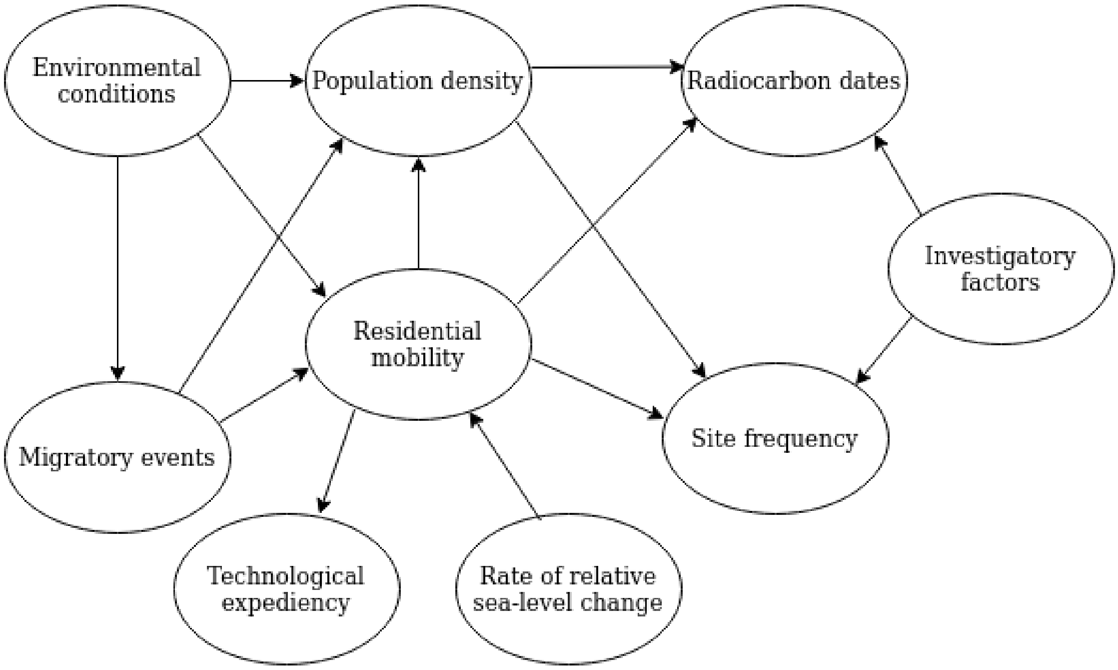


Figure 5.9: Suggested causal model for the drivers behind the frequency of radiocarbon dates and shoreline dated sites through the Mesolithic of south-eastern Norway.

The DAG presented for the fourth paper is clearly the less complete and most speculative of the ones presented in this chapter. Several of the postulated mechanisms are likely missing mediating and potentially confounding variables that could be critical for properly understanding these relationships, and the question of temporal resolution is also critical following from the potential feedback effects that have been suggested to exists between several of these variables. The model nonetheless outlines an array of possible relationships to explore, all of which have some potential albeit uncertain avenues for fruitful operationalisation.

5.6 Chapter summary

This chapter has laid out the arguments and evidential claims that underlie each of the four papers of the thesis. Furthermore, developing explicit hypotheses have been argued by many to reduce accommodative argumentation, thereby reducing research bias, increasing reproducibility and potentially facilitate a move towards unveiling causality (see last chapter and e.g. Betts et al. 2021; Platt 1964). Consequently, the chapter also presented suggestions for causal graphs pertaining to the empirical patterns identified in the papers, aimed at offering some potential avenues for future research. While future studies will undoubtedly lead to the adjustment of these models, having explicitly laid these out can help focus and direct avenues of criticism and further research efforts, irrespective of the life-span of the models.

Chapter 6

Concluding remarks

Any attempt at describing or explaining the past involves imposing abstractions that will necessarily hide variation and idiosyncrasies that could prove to be both important and interesting. Quantification is one system of representation that allows stringent reporting and handling of uncertainty, while providing comparability and analytical feasibility for large amounts of data across multiple scales. Furthermore, the material that has been and continues to be generated by archaeology is getting increasingly vast, and any attempts at getting a basic overview, let alone draw inferences concerning past societal systems, require frameworks designed to handle this flood of information. Consequently, at the cost of reducing the archaeological record to the logic of numbers, quantification offers the potential to yield insights that are simply not achievable by other means.

Shennan (1988:1) quotes Colin Renfrew has having stated that 'the days of the innumerate are numbered'. However, Kristiansen (2004:80) later stated that quantitative methods were 'disastrously out of fashion' in archaeology. This picture has changed considerably since 2004 (e.g. Kristiansen 2014), and increased enthusiasm for such approaches need to be continuously tempered by a concern for the answers they can hope to answer, the nuances that they might subsume, and the intricacies involved with critically employing such methods in an informed manner. However, the potential of quantitative and computational approaches is arguably far from having being sufficiently utilised in Norwegian archaeology.

This thesis has shown some of the advantages quantitative methods can have. Through the four papers of the thesis, focus has in part been directed towards exploring and deriving methods that can be used to meaningfully handle the increasingly massive material associated with the Norwegian Mesolithic. In one sense, therefore, the thesis can be considered to have contributed to fundamental descriptive and exploratory tasks related to the first overarching research question posed in the introduction (see Section 1.2): i) What is the extent and quality of the archaeological record from Mesolithic Norway? However, as the second research question implies, the answer to this also have clear substantive implications: ii) What consequences does this have for our disciplinary agenda and for our understanding of the Norwegian Mesolithic? As is made clear both through the papers and this introductory text, the elucidated patterns can be directly related to societal dimensions such as patterns of settlement, mobility and demographic developments – all of which have been heralded as fundamental to our understanding of past hunter-gatherer societies.

Furthermore, the project was conducted within a framework of open science with all underlying data, text, and code being shared with the thesis. This was done both to allow others to assess the inner workings of the arguments being made, to allow methods and data to be used in other contexts or for other research questions, and, in keeping with an epistemic modesty laid out in Chapter 4, to facilitate critical engagement. In the same vein, Chapter 5 laid out what I believe are the fundamental inferential steps taken in each of the papers, and presented the main findings of each paper as concrete hypotheses instantiated as causal graphs. In presenting the central arguments and inferential leaps taken, the hope is both to facilitate and motive critical engagement, and pave the way for pursuing these issues in future research. Providing all underlying data and code, and laying out arguments and hypotheses as explicitly as possible is both a challenge, in terms of attempting to expound what processes might have generated the data, and risky, in the sense that any mistakes, blind-spots or omissions will be easier to identify. However, at the price of putting academic pride at risk, there can be little doubt about the disciplinary benefits of clarity and transparency.

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