Fishing for ways to thrive

Integrating zooarchaeology to understand subsistence strategies and their implications among Early and Middle Mesolithic southern Scandinavian foragers

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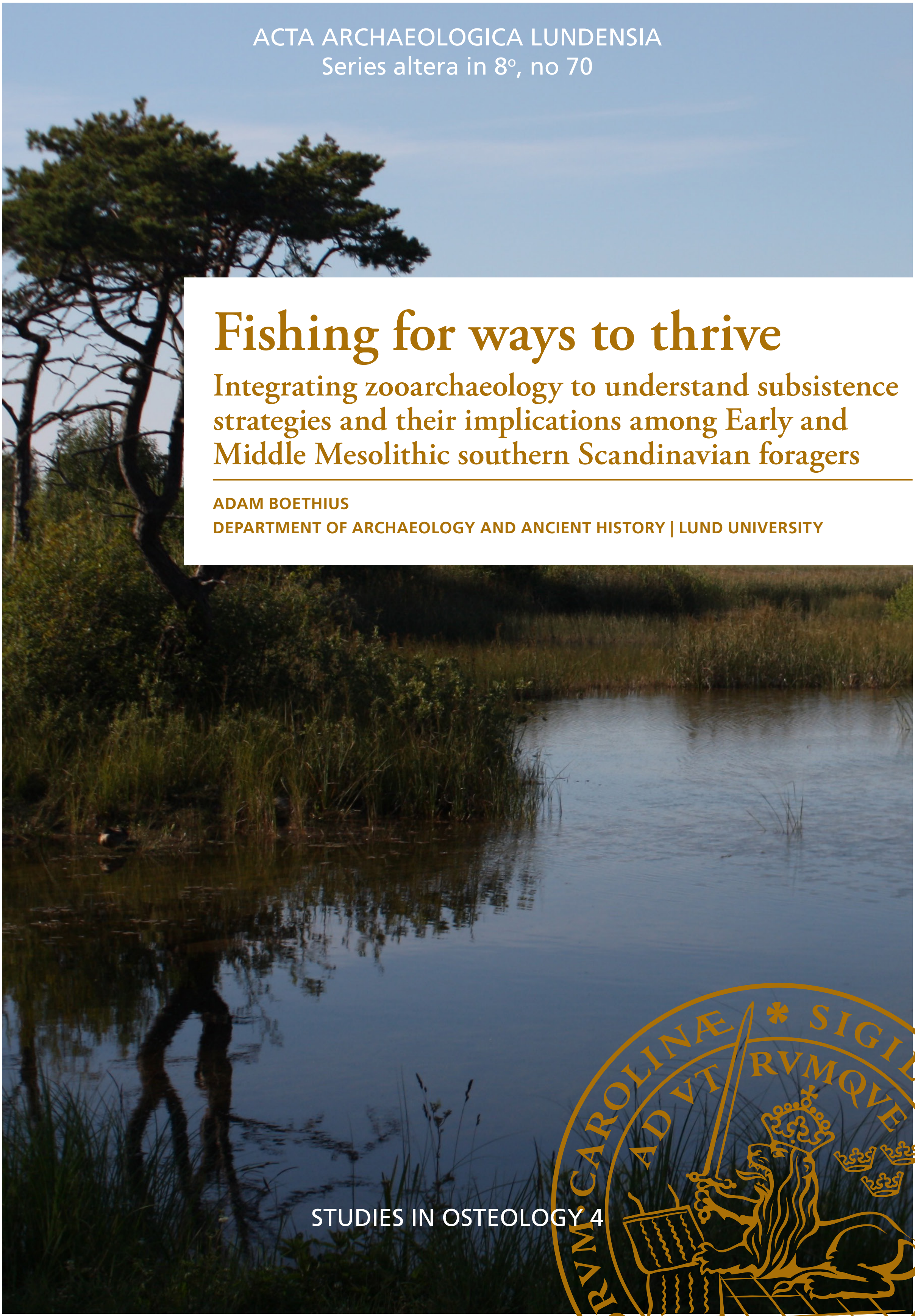

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Fishing for ways to thrive

Integrating zooarchaeology to understand subsistence strategies and their implications among Early and Middle Mesolithic southern Scandinavian foragers

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STUDIES IN OSTEOLOGY 4

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Studies in Osteology 4

Front cover photo by Jan Apel: Svajde vät on Gotland
Back cover photo by Adam Boethius: 9500-year-old fish bones
‘Bait the hook’ photo by Anna Fritz

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‘Bait the hook well; this fish will bite’

William Shakespeare

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Abstract

The purpose of this thesis is to evaluate and deduce the varied lifeways of Early Holocene foragers in southern Scandinavia. By taking an interdisciplinary approach, zooarchaeological data have been applied to the study of different aspects of Early and Middle Mesolithic subsistence, in order to frame a discussion concerning our current understanding of culture and life in early north European societies. Three different sites/areas are the focus: Norje Sunnansund, Huseby Klev and Gotland/Gisslause. However, all available material from the chosen temporal and spatial frame have been incorporated to enable holistic discussions. The three focus areas combined comprise all available coastal settlements with well-preserved organic material from the Early Mesolithic period, which has led to discussions centred on the use of aquatic resources and the importance of fish.

To address the different aspects of Early and Middle Mesolithic subsistence, multiple approaches have been taken, whereby zooarchaeological methods have been combined with statistical, chemical, physical and ethnographical tools for analysis. The focus has varied between fish storage and conservation practice, by presenting evidence for delayed-return subsistence strategies through means of large-scale fish fermentation, and discussions concerning the evidence for a delayed-return lifestyle and sedentism, through the study of zooarchaeological assemblages. Furthermore, taphonomy is highlighted and discussed in order to address the many biases affecting the recovery of freshwater fish bones and the consequences for detecting a freshwater fish-based diet. Pioneer subsistence strategies are studied, and changes through time are highlighted in marine coastal regions. In addition, the reservoir effect in radiocarbon dating (^{14}C) of human bones has been examined to evaluate the consequences of a freshwater reservoir effect stemming from a large dietary input of freshwater fish. Furthermore, stable isotopes values, δ^{13}C and δ^{15}N, in the collagen from all available Early and Middle Mesolithic humans have also been analysed and modelled, in order to evaluate the importance of each individual protein source in the diet.

The results from the different approaches taken indicate that humans relied on fish to a higher degree and from an earlier date than previously assumed. This has implications for how Early Holocene societies are interpreted; indicating the use of delayed-return subsistence strategies, diminishing mobility and emerging sedentism already existed during the Early Mesolithic period. Overall, the results of this thesis suggest a growing territoriality, which implies that the emergence of social stratification is conceivable at an early stage of Scandinavian prehistory and offers an insight into the lifestyle of Early Holocene foragers at latitudes around 55–59° N.

Appended papers

I. Boethius, A. 2016. Something rotten in Scandinavia: The world's earliest evidence of fermentation. *Journal of Archaeological Science*, 66, 169–180. Reproduced with permission from Elsevier.

II. Boethius, A. 2017. Signals of sedentism: Faunal exploitation as evidence of a delayed-return economy at Norje Sunnansund, an Early Mesolithic site in south-eastern Sweden. *Quaternary Science Reviews*, 162, 145–168. Reproduced with permission from Elsevier.

III. Boethius, A. 2018. The use of aquatic resources by Early Mesolithic foragers in southern Scandinavia. In: Persson, P., Skar, B., Breivik, H. M., Riede, F. & Jonsson, L. (eds) *The Ecology of Early Settlement in Northern Europe: Conditions for Subsistence and Survival*. 311–334. Sheffield: Equinox. Reproduced with permission from Equinox.

IV. Boethius, A. 2018. Huseby Klev and the quest for pioneer subsistence strategies: Diversification of a maritime lifestyle. In: Persson, P., Skar, B., Breivik, H. M., Riede, F. & Jonsson, L. (eds) *The Ecology of Early Settlement in Northern Europe: Conditions for Subsistence and Survival.* 99-128. Sheffield: Equinox. Reproduced with permission from Equinox.

V. Boethius, A., Storå, J., Hongslo Vala, C. & Apel, J. 2017. The importance of freshwater fish in Early Holocene subsistence: Exemplified with the human colonization of the island of Gotland in the Baltic basin. *Journal of Archaeological Science: Reports*, 13, 625–634. Reproduced with permission from Elsevier.

VI. Boethius, A. & Ahlström, T. 2018. Fish and resilience among early Holocene foragers of southern Scandinavia: a fusion of stable isotopes and zooarchaeology through Bayesian mixing modelling. *Journal of Archaeological Science.* 93, 196-210. Reproduced with permission from Elsevier

1. Prologue

The outline for this thesis was formed in a muddy hole in a field outside Sölvesborg, in Blekinge, south-eastern Sweden, as I and my colleagues on the E22 Sölve-Stensnäs project were excavating the site of Norje Sunnansund. I had, prior to the muddy hole, been fortunate enough to have participated in the preliminary excavation analysis of the zooarchaeological remains from three $1m^2$ squares from the site. The results from these test pits had generated a high species diversity as well as a relatively large number of fish bones from a limited amount (3 litres) of sieved soil (Boethius and Magnell, 2010). Fortunate, because the relatively large number of fish bones was only found because my colleague (and later co-supervisor) Ola Magnell lived fairly close to the site and found the fish bones after he went there to extract a soil sample, which he then brought home to his backyard to sieve through, using fine meshed sieves. Without prior knowledge that fish bones could be expected on the site, it is likely that we would have used larger mesh sizes during the final excavation. This would have left us with much lower numbers of fish bones (note the 94% recovery decrease when doubling the mesh size[1], as presented in paper I) and it would have been highly unlikely that any of the ideas that developed during the final excavation would have been formed. Nevertheless, we did apply fine-mesh water sieving on the excavation, and the results were spectacular (from a fish bone-recovery point of view) (Fig. 1). The quantity of recovered fish bones stood out as something out of the ordinary, and it sparked an interest to find out why so many fish bones were found here and, more importantly, what that implied for the time period in general.

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[1] Here size equals the length of each mesh side (from 2.5 to 5mm), which means that the actual mesh area (the hole) is quadrupled.

Figure 1 The fish bone material from 1m^2 of the cultural layer from the oldest phase at Norje Sunnansund (in total 211m^2 were excavated from this layer). Photo: Adam Boethius.

Prior to the start of the excavation of Norje Sunnansund, and because of the fish bones recovered during the preliminary excavation, I hypothesized that a decreased mesh size would largely increase the recovery of fish bones, which gave us the opportunity to apply fine-mesh sieving on a large scale during the final excavation. This meant that we water sieved all of the excavated soil, about half of it while using a relatively fine meshed sieve and the other half using a somewhat larger mesh (2.5 and 4 mm). This yielded good results, in fact much better than I could have ever imagined. By the end of the excavation we had collected close to 200,000 fish bones, which, if put in a comparative context, is almost 10 times the amount of all the fish bones recovered from all contemporaneous Scandinavian sites combined; in addition, it was all from freshwater fish. This meant that, by decreasing the mesh size on the sieves, compared with normal practice for Swedish contract archaeology when excavating Mesolithic cultural layers, we had observed a ‘new’ phenomenon. This is perhaps not unexpected, as it has long been known that the recovery of fish bones is highly dependent on the methods used during excavation, and many studies highlight the large loss in fish bone recovery when using larger mesh sizes for sieving the soil (Enghoff, 2007; Hultgreen et al., 1985; Payne, 1972; Segerberg, 1999; Wheeler and Jones, 1989). However, because we were able to collect more fish bones from Norje Sunnansund by applying a finer meshed sieve than commonly used, it is conceivable that the same result could have arisen on previously excavated sites (which usually had not been sieved at all), and the results could have been similar to those arising at Norje Sunnansund. In other words, what we found at Norje Sunnansund might not be different to what could be found elsewhere, if fine-meshed water sieving is applied and if preservation is favourable, especially if a new coastal settlement should be found and excavated.

Following the final rescue excavation of Norje Sunnansund, I started to consider the potential of the observations made there and, consequently, I started to loosely formulate the initial hypothesis on which my PhD project is built: *freshwater fish must have been more important (than previously considered) for the first humans settling in Scandinavia and this must have had broad implications on how their societies were constructed*. When I started thinking along the lines of a freshwater fish-based Early Mesolithic subsistence, Norje Sunnansund was the only observed Scandinavian Early Mesolithic settlement where freshwater fish could be demonstrated to have been a major subsistence source. This meant that most research had focused on a diet based on terrestrial mammals and the consequences thereof, e.g. high mobility, low birth rate, low population density, etc. Therefore, in order to suggest a general freshwater-based subsistence in this period, I would have to propose revisions to how the people from this time period were perceived. Furthermore, I would have to explain why I wanted to show the importance of freshwater fish, particularly because prior discussions concerning Early Mesolithic subsistence strategies often have centred around terrestrial hunting, even though the increased bioproduction in eutrophic (over-growing, hypertrophic) lake environments, and the consumption of fish, has been suggested as important to Mesolithic humans (Welinder, 1978). Therefore, the only way to investigate the importance of freshwater fish during the Early Mesolithic (in a plausible way) would have to be through diverse evidence that addressed prior assumptions, i.e. I would need to apply a wide variety of methods to different sources of information and investigate how each of them related to the importance of fish in the human diet. Furthermore, I would need to investigate the foundation on which prior assumptions had been built and examine whether they could be interpreted differently.

My initial means of addressing the general research trends was through the use of one of the most essential and basic osteoarchaeological theories: taphonomy. In short, taphonomy explains the decay of organic tissue and deals with all the plausible biases affecting an organic material (see Theoretical perspectives, Chapter 4). Taphonomy is the obvious starting point when dealing with fish remains, because they are more fragile and smaller than mammal bones and, consequently, perish more easily, both before and after they end up in the ground, and so are more difficult to recover (Wheeler and Jones, 1989). Fish bones are also more prone to destruction by external forces, such as gnawing and digestion, compared with mammal bones (Butler and Schroeder, 1998; Jones, 1986;

Nicholson, 1993). Furthermore, if fish remains are subjected to mechanical manipulation, e.g. trampling, they are easily crushed into small unrecognizable pieces (Jones, 1999; Wheeler and Jones, 1989). Indeed, the chemical properties of fish bones are different from those of mammals, and a comparative lack of the amino acid hydroxyproline has been suggested as a major factor explaining why fish bones are more unstable than mammal bones and consequently more prone to dissolution by chemical leaching (Szpak, 2011). This effect has also been suggested to be more severe in colder climates (Szpak, 2011:3368), which adds to the problems of finding fish bones in Early Mesolithic Scandinavian contexts.

However, it is one thing to say that something is easily missed or unaccounted for, i.e. by stating that absence of evidence is not evidence of absence, but quite another to say that the things we are not seeing were originally there. Therefore, it is plausible for people to have consumed large amounts of fish and the fish bones themselves to have perished over the years and left no evidence; but it is equally plausible that people were not consuming large amounts of fish and therefore there is no evidence of fish bones. If the only way to argue the importance of fish is by stating taphonomic (recovery and preservation) reasons, it makes the claims impossible to falsify and as such they are of little scientific value (Popper, 1963). Thus the importance of fish cannot be suggested based solely on claims of missing fish bones[2]. This is because of the complexity and variability of the taphonomic history of most archaeological assemblages, which complicates the comparison and interpretation of zooarchaeological materials. For example, fish have more bones in their bodies than mammals and can be argued to occur more frequently on an archaeological site for this reason. Fish are also comparably small, i.e. if comparing with terrestrial ungulates it can require hundreds of fish to obtain the same amount of meat as, e.g., from one red deer (*Cervus elaphus*) or one wild boar (*Sus scrofa*), which is probably one reason why terrestrial hunting often dominates discussions about Early Mesolithic subsistence (cf. Research history, Chapter 3.2). Therefore, comparisons of mammal and fish bones in subsistence studies are often complicated because of general difficulties in tracking the taphonomic history of a bone assemblage. In other words, and depending on context and quantities, preservation is seldom close to perfect, it is often not possible to tell whether dogs had been allowed near the fish bones, and it is often hard to tell whether small fish were consumed whole. Furthermore, it can be problematic to tell whether fish bones were buried straight after the flesh was eaten (so nobody had the chance to step on them). We cannot always tell whether bones from one species or a group of species were systematically discarded elsewhere, e.g. if fish had been filleted on a canoe and the bones discarded in the water, or if only the meat from a terrestrial animal was removed and brought from the kill site. In addition, fine-mesh sieving

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[2] Indifferent if the claims are based on poor preservation or on a lack of sieving with fine-meshed sieves during the excavation.

has seldom been applied on entire excavations (to ensure that fish bone concentrations are not overlooked). Therefore, taphonomy has a central role in providing a hypothetical explanation for fish bones being absent, because it provides an alternative and equally plausible account to the original interpretation, which has led to the consumption of freshwater fish seldom being discussed. Thus inference from other evidence would be needed to study successfully the importance of fish in Early Holocene subsistence, i.e. a better and more plausible explanation of the available data had to be offered.

Prior to starting my PhD project, I had a series of proposed entries (planned articles) of how to evaluate the importance of fish and the development over time that led to the Late Mesolithic aquatically dependent sedentary societies of the Ertebølle culture. The explanations involved the expected ecological bonanza[3] experienced by humans living in an environment of freshwater systems that were becoming marine, as a function of increasing salinity in the Baltic Sea. However, as the project proceeded, most of the initially asked questions and paths to demonstrate this bonanza and the following shift to sedentary societies changed. Instead I found myself arguing for the possibility that these types of societies developed much earlier than the Late Mesolithic period and that the Early Mesolithic societies were in fact adapted to highly nutritious freshwater systems, which then changed to marine systems when the surrounding waters became saline. Consequently, I found myself starting to argue for a similar societal structure in the Early Mesolithic period, several millennia prior to the Late Mesolithic Ertebølle culture.

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[3] Increase in available biodiversity and biomass.

2. Introduction

Foragers[4] can be defined as human groups who primarily feed on wild, i.e. non-domesticated, food and practise hunting, gathering and fishing as their main base of subsistence (Kelly, 2013:2). The collected knowledge about foragers spans a few hundred years of research and covers at least 300,000 years of human existence (Hublin et al., 2017; Richter et al., 2017), and includes many different modes of foraging. Needless to say, that makes the concept of foragers very broad and includes many human groups or societies, from the first humans living in Africa to humans expanding out of Africa to Europe, Asia, Australia and America; and it includes humans in a wide variety of environments, from semi-desert and rainforest to arctic conditions. Furthermore, it involves human groups living as foragers at a time when this was the only known lifestyle on the planet, it involves human groups who invented agriculture and domesticated animals and it includes human groups who continued to forage when neighbouring groups started to practise agriculture and animal husbandry. In addition, it encompasses humans who lived a foraging lifestyle when encountered by humans who did not and it includes groups of people that today live in marginalized areas of the world, either as groups completely unaware of modern societies or groups who frequently or only occasionally interact with the rest of the world.

In the majority of research, foragers have been referred to as hunter-gatherers. This is misleading because it implies a low importance of fish in the diet. In recent years the term hunter-fisher-gatherers has increased in popularity, even though fisher is still often not included[5]. This indirectly generates a difference between hunter-gatherers and hunter-fisher-gatherers, as it creates an imaginary boundary between groups being referred to as either one or the other, and underlines uncertainties on the role of aquatic resources (Bailey and Milner, 2002). Therefore, and without a scientific discussion or investigation of the subsistence strategies used, it biases the diet discussions concerning these groups of people and hampers the discussions regarding their base of subsistence, as well as creating a separation in the research literature based solely on semantics, which has a tangible effect of how these societies and humans are perceived.

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[4] Used here not according to Binford's (1980) separation of foragers and collectors but as a word to avoid the unfortunate semantic differentiation of different types of societies living mainly on wild, non-domesticated, resources (see below).

[5] Even though researchers working with foragers are well aware that fish has been part of most foraging diets.

Interestingly, this separation can also be observed within the framework of research about prehistoric foragers in a Scandinavian setting. Early Mesolithic research trends often focus on different aspects of terrestrial ungulate hunting (cf. Research history, Chapter 3.2). This probably stems from the low quantities of fish bones recovered from Early Mesolithic sites (see fig. 10) and a general lack of coastal settlements from the period in question, i.e. Late Palaeolithic and Early Mesolithic coastlines are generally found on the seafloor because of the transgression that submerged the areas (Bailey, 2014). Most researchers concerned with the time period in question are well aware that fish was part of the diet and often mention fish as such (cf. Research history, Chapter 3.2). Furthermore, fish has been demonstrated as a food source from the Late Palaeolithic onwards, through finds of fish bones from more than 50 different Palaeolithic (Adán et al., 2009; Conard et al., 2013; Cziesla, 2004; Hahn, 2000; Russ and Jones, 2009) and early post-glacial sites (Aura et al., 2002; Stiner and Munro, 2011). Fish as a food source has also been established through finds of fishhooks (Gramsch et al., 2013) and stationary fish traps (Nilsson et al., 2018), and the indications of both Palaeolithic and Mesolithic human stable isotope signals, where fish has been demonstrated to be part of the diet (Lidén, 1996; Lidén et al., 2004; Richards et al., 2001; Terberger et al., 2012). However, the difficulties of showing *how* important fish were to the Early Holocene Scandinavian population, and the fact that most research has focused on different aspects of ungulate hunting, have led to the impression that Early Mesolithic societies should be perceived as terrestrial big game hunters, and statements such as ‘Early Mesolithic subsistence economies were based largely on hunting, with red deer, boar and roe deer most important among the prey’ (Jochim, 2011:122). This stands in contrast to Late Mesolithic societies, which, in northern Europe, are more often perceived as subsisting on a fish-based diet (Jochim, 2011:134). In order to answer whether this dichotomy does in fact exist[6] or whether this view is similar to the unfortunate semantic differentiation of foragers (and fish as an important dietary source is largely overlooked), this thesis is situated in a temporal and spatial framework covering the Early and Middle Mesolithic period (around 11,500–7500 cal. BP) in southern Scandinavia. The main investigated sites come from a time period that stretches roughly from 10,500 to 7500 cal. BP and, as such, the first millennia of the Early Mesolithic period is not directly studied. Furthermore, and even though subsistence in the Ertebølle culture, during the Late Mesolithic period, and the Pitted Ware culture, from the Neolithic period, are also based on a foraging lifestyle[7], this study has been limited to the timeframe mentioned. This has been

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[6] A dichotomy dealing solely with current views on Mesolithic foragers and not if these foragers defined themselves as fishers or big game hunters (if they indeed defined themselves according to their subsistence at all, which can be debated).

[7] Whereby it would seem logical to incorporate these periods as well, in order to present a full picture of the prehistoric foraging spectrum of southern Scandinavia.

done both because of restrictions in available and known archaeological material (i.e. from the earliest part of the Early Mesolithic), but also to be able to delve deep enough into the chosen temporal and spatial area to study these human cultures to their full extent[8]. However, even though both the first and the last part of the Mesolithic have been omitted it has, on occasions, been possible to make inferences and interpretations on a more general basis that include these periods, based on the results presented in the different papers.

2.1. Aims and purposes

Human societal structure can, to a certain degree, dictate what is seen as the necessities of life, and how the society is constructed can be paramount in deciding the means of obtaining those necessities, e.g. where multiple lifeway strategies are available 'culture' limits and dictates life choices and subsistence practices (Ogburn, 1964). Therefore, by reversing the above argument, it is also possible to study the lifeways and cultural expressions of a human society through its dietary habits and subsistence practices. Consequently, the purpose of this thesis is to study the varied lifeways of Early Holocene foragers in southern Scandinavia by means of their subsistence strategies. This will be done mainly through examination of the bone remains from the available archaeological sites. By seeking knowledge of subsistence strategies, the aim is not only to study the diet or the exploited fauna of these foragers, but to connect the available evidence to a larger framework. This includes diet but also encompass cooking methods, food storing, food procurement strategies, exploitation patterns, mobility, choice of living environment, and the implications of these choices and actions. The thesis therefore follows the logic of the phrase '*Dis-moi ce que tu manges: je te dirai ce que tu es*' [Tell me what you eat and I will tell you what you are], coined in the early 19th century by Brillat-Savarin (1994) [1825], or as applied in a modern-day saying, 'you are what you eat'. The overall purpose can therefore be summarized in one sentence: *I aim to study their subsistence strategies so I can tell you who they were.*

While Mesolithic diet and faunal exploitation have been studied previously on a number of occasions (cf. Research history, Chapter 3.2), the focus here is upon how important aquatic resources were to the Early and Middle Mesolithic human population. The main question addressed is: *How important was fish to Early and Middle Mesolithic south Scandinavian forager subsistence and what are the*

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[8] The chosen temporal and spatial framework is also optimal for studying foragers without having to consider the complex situation arising when farmers and pastoralists enter the equation; it allows the 'unaffected' foraging lifestyle to be studied in full.

implications, regarding a high dietary importance of fish, for our understanding of these societies? In order to investigate this overall purpose, each of the different papers presented in this thesis follows its own path with its own goals. However, the papers all centre around the importance of aquatic resources, i.e. fish, and how to study and evaluate the importance of fish to Early Holocene human societies in Scandinavia. Combined, the different goals of the papers are brought together to meet the overall purpose. The goals of the different papers are as follows.

In paper I, the goal is to answer the question of how large-scale storage can be traced in archaeological foraging contexts, what preservation techniques were applied to large quantities of fish, and how the possibility of demonstrating large-scale storage impacts our understanding of early foraging societies in northern Eurasia. By providing evidence of fish fermentation and long-term storage in this paper, the emergence of (semi)-sedentary societies is implied, which then paves the way for the following paper.

Consequently, in paper II, other methods of detecting a high degree of settlement permanence and delayed-return subsistence strategies in the Scandinavian Early Mesolithic period are investigated, by analysing the zooarchaeological remains at Norje Sunnansund. More specifically, the goal is to answer questions of whether it is possible to identify the presumably many active strategies adopted to ensure survival when reducing residential mobility, and how circumstantial evidence can provide information about the level of settlement permanence.

In paper III, taphonomic challenges are discussed and related to archaeological evidence for the use of aquatic resources during the Early Mesolithic period. The insights gained from studying the site of Norje Sunnansund are used to highlight the need for a profound knowledge in taphonomy and the many sources of error at play when working with aquatic remains in general and freshwater fish remains in particular. Therefore, the goal of this paper is to illustrate the difficulties involved in studying fish bone assemblages and translating them into subsistence patterns, which is done by delivering different scenarios of taphonomic loss. By addressing the difficulties of detecting a diet based on freshwater fish, this paper examines how Early Mesolithic societies are perceived and evaluates the evidence for how many people freshwater fishing could have sustained at the Norje Sunnansund site.

In paper IV, the bone material from the Mesolithic site of Huseby Klev, in Bohuslän on the Swedish west coast, is examined. The aim of this paper is to use the zooarchaeological assemblage and let it take centre stage in the debate regarding the Scandinavian pioneer settlers. By recognizing the potential of the bone material from Huseby Klev, the paper aims to advance our knowledge of the Scandinavian pioneers in marine environments and answer questions regarding their subsistence strategies, and how and why these strategies changed and developed over time.

In the first joint paper of the thesis, paper V, the goal is to examine the importance of freshwater fish to Early Holocene foraging societies, by using the colonization of the island of Gotland, in the Baltic Sea, as a proxy. By studying the freshwater reservoir effect on a number of radiocarbon dates and by presenting evidence from the recent excavation of the Early Mesolithic site Gisslause, the paper seeks to connect these two types of evidence. This is done firstly, to suggest a reconsideration of the importance of freshwater fish, and secondly, to advocate the use of alternative methods to catch these elusive dietary indicators.

In the second joint paper, paper VI, the goal is to elucidate if, and how, source-specific dietary estimations can enhance our understanding of Early Holocene diet in southern Scandinavia. By including all available human stable isotope values from southern Scandinavia and by analysing them in a Bayesian mixing model, using a baseline of contemporaneous food sources, the paper aims to illustrate the importance of individual protein sources in the diet of Scandinavian Early and Middle Mesolithic humans. Furthermore, this paper aims to show the importance of also using the zooarchaeological record from a site when analysing human stable isotopes, and that zooarchaeological information can help provide suitable proportion data, when comparing specific protein sources, for both general (within an environmental and temporal framework) and site-specific diet estimations.

3. Research history

Because of the comprehensive nature of foragers, and because of the temporal and spatial framework in which the thesis is situated, only the most relevant research is mentioned here. More specifically, this includes discussions related to complexity among foragers[9], discussions and data concerning subsistence and diet in Scandinavian Early and Middle Mesolithic contexts (cf. fig. 3 for a comprehensive overview of all Scandinavian Mesolithic sites mentioned in the text), and the origins of fish bone analyses in Scandinavia.

3.1. Complex foragers

3.1.1. Definitions

In order to discuss earlier work on complex foragers and to follow the discussions in this thesis, two definitions need to be made: *sedentism* and *complexity*.

3.1.1.1. Sedentism

The word sedentism follows the definition made by Susan Kent (1989), in which sedentism should be viewed as a group of people spending most of the year at one location even if 'at other times during the year the group leaves, returning to the community after short, often seasonal, absences' (Kent, 1989). Therefore, the use

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[9] This approach is selective and, while it focuses the ethnographic parallels into manageable entities, it does ignore alterative stories from large parts of the world. However, there are good reasons justifying this approach. Firstly, because the aim of this thesis is to investigate the importance of fish in Early Holocene southern Scandinavia, the parallels used needed to encompass similar environments, which effectively hindered comparison with many of the traditionally egalitarian foraging societies from lower latitudes around the world. Secondly, as Scandinavian Early Holocene societies have traditionally been seen as mobile societies subsisting mainly by terrestrial hunting, it is interesting to explore whether this is the only option available for foragers in this type of environment and at corresponding latitudes, thus highlighting the capacity and likelihood of variability among foragers. Therefore, since mobility as a subsistence strategy has already been examined from many different angles, contexts and forums, the focus here is on the opposite, i.e. sedentism as a concept and the implications thereof. Therefore a research history of complex societies is pursued and more egalitarian societies are omitted. The latter are not forgotten, however, and ethnographical accounts of mobile and egalitarian foragers are noted at appropriate places in the thesis.

of the word sedentism, and semi-sedentism[10] which is also used on occasions, includes a wide number of mobility strategies that can vary throughout the years and include different configurations within a group of people (Kelly, 1992). These mobility strategies have often been considered as residential (the movement of the entire base camp from one location to another) or logistical (the movement of smaller groups to meet task-specific demands while retaining a base camp elsewhere) (Binford, 1980). However, while these divisions might seem straightforward, there is often only a relative boundary between what is considered sedentary and what is considered mobile, based on a number of relational criteria. These include the group's number of residential moves per year, such that a group can be considered to be residentially mobile as long as most of the group leaves the location for some period of time (Kelly, 1983). The definitions can also be based on the average distance per residential move, the total distance covered through residential mobility per year, the total area covered per year, or the length of occupation of a winter settlement site (Kelly, 1983). Because of the many parameters that have been used to define a group's mobility, the definition of sedentism has also varied greatly, depending on the researcher and research area. Consequently, definitions vary between total permanence, where sedentism is defined as 'human groups which stay in one place all year round' (Higgs and Vita-Finzi, 1972:29), to suggestions that sedentary life can be used: 'where at least for the greater part of the year the greater part of the population lived together in increasing numbers on one spot' (Reed, 1977:551). When definitions of sedentism aim to incorporate a larger degree of variability in the settlement systems, they can be seen to follow the example given by Rafferty (1985), which is adopted from Rice (1975), where she sees sedentary settlement systems as 'those in which at least part of the population remains at the same location throughout the entire year'(Rafferty, 1985:115). In other words, the definition of sedentism can incorporate the absence of group members during certain parts of the year, cf. the discussion in Rafferty (1985).

In order to incorporate relative comparisons while also recognizing mobility variations from year to year, sedentism, as used here, is inclusively defined and encompasses a place that was perceived as home for long-term occupation. Sedentism therefore implies a low degree of residential mobility and a limited number of locations that at any given point in time are perceived as home to the members of a particular group of people. With this definition, sedentism allows a larger community to be split up during parts of the year and to reside at different locations, assuming home, in the general view among the people in the group, is

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[10] The words semi-sedentism and sedentism are considered here to be analogous and do not carry different connotations. Their varied use in the papers of the thesis is a reflection of the context of each publication.

related to a particular settlement or a limited territory[11] where most of the group members spend most of the year. If related to Lewis Binford's view on mobility (Binford, 1980; 2001), sedentism should, therefore, be considered for societies with low residential mobility and a varying degree (large and small) of logistical mobility. In other words, sedentism is when a group of people moves the entire home base a limited amount of times, but where a limited group of members of the larger community can move away for shorter absences to perform selected tasks (e.g. raw material procurement or hunting).

3.1.1.2. Complexity

Complexity itself is also a matter of definition and often follows a cultural-specific attribution of the word; it is generally considered unwise to suggest a worldwide definition of complexity because of the variability of human societies (Fitzhugh, 2003). Therefore, the definition of complexity used here follows Ben Fitzhugh's recognition that certain characteristics are found among complex foragers, such as: 'a relative high degree of residential permanence, higher population densities, multi-seasonal food storage, competition over the rights to productive resource locations and accumulated surplus, status asymmetry, and organized warfare' (Fitzhugh, 2003:3). Correspondingly, complexity among foragers can be seen as: *sedentary and territorial foragers who live in organized unequal ranked societies and practise delayed-return subsistence strategies*. This definition follows on from Fitzhugh's view on complexity as 'demonstrably more socially differentiated (horizontally and/or vertically) than other societies under comparison' (Fitzhugh, 2003:3). The comparisons made in the papers included in this thesis consider both prior assumptions regarding Early Mesolithic complexity among Scandinavian foragers and anthropological accounts of non-socially stratified (i.e. egalitarian), non-sedentary and non-complex foragers.

3.1.2. Previous research

One of the first indications that anthropology recognized the possibilities of complexity among foraging societies was the contribution of Wayne Suttles (1968) in the *Man the Hunter* publication (Lee and DeVore, 1968) from the famous conference of the same name. He was one of the first to describe the north-west coast native societies of America as having high population densities and

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[11] This implies that the location of the actual house/hut does not have to be at the exact same spot, even though it can be, as e.g. where stationary fishing equipment was deployed, where storage facilities were kept, where the processing of food products was carried out, where the crafting of tools was performed or where the dead were buried or excarnated (see Discussion, Chapter 8.6.1), etc. It should rather be seen as a limited zone encompassing all of the mentioned activities/areas, which taken together, in the mind of the occupants, is recognized as 'home'.

semi-sedentary large residential groups with social stratification mitigated by a large division of wealth, i.e. complex societies. However, complex elements of these north-western societies had been observed much earlier by anthropologists, e.g. Frank Boas, albeit at this early stage perhaps not recognizing the significance of their complexity, and much of Boas' observations were not published until years after his death (Boas, 1966), or because the complexity was merely thought of as an environmental adaptation, i.e. natural food abundance allowed these people to increase their cultural level (Gross, 1898).

In *Man the Hunter*, George Murdock also describes the complexity of north-western tribes and suggests a reliance on dependable abundant aquatic resources as the main factor allowing these societies to become both complex and sedentary (Murdock, 1968). However, the majority of anthropologists in the late 1960s and early 1970s viewed this as an anomaly and not as a 'normal' variation of forager behaviour. It was not until the second half of the 1970s that complexity among foragers became more widely recognized, with anthropologists starting to recognize this mode of life as part of the variability among foragers. In 1978 Thomas King published a paper on complexity among prehistoric foragers in California (King, 1978) and some years later in the early 1980s researchers such as James Woodburn (1980; 1982) discussed and minted the delayed-return concept. David Yesner (1980) discussed prerequisites for maritime forager societies and Alain Testart proposed that the relevant factor for the development of inequalities is 'the presence or absence of a storing economy' (Testart, 1982:525). Therefore, Testart's paper relates complexity among foraging societies with food-storing capacity, which sparked many discussions over the coming years (Cannon and Yang, 2006; Cunningham, 2011; Frink and Giordano, 2015; Halstead and O'Shea, 1989; Ingold, 1983; Keeley, 1988; O'Shea, 1981; Rowley-Conwy and Zvelebil, 1989; Stopp, 2002; Testart, 1982; Wesson, 1999) and paved the way for interpreting evidence of suggested food storage practices in the archaeological record, e.g. by Pavel Dolukhanov (2008), Anne McComb and Derek Simpson (1999), Michael Ryan (1980), Matthew Sanger (2017), Olga Soffer (1989) and Peter Woodman (1985a).

On the topic of identifying complexity among ancient foragers, it is also important to mention some of the many papers written by Peter Rowley-Conwy. In 1983, as the first to introduce the concept of complexity in research on Scandinavian prehistoric foragers, he exemplified the complexity of the Late Mesolithic Ertebølle culture in Scandinavia by, among other things, showing analogies with the north-west coast of America (Rowley-Conwy, 1983). He suggested sedentary settlement systems existed in the Ertebølle culture, with permanently occupied base camps and seasonal-use camps. In 1989, Rowley-Conwy and Marek Zvelebil discussed the risk-reducing properties of storage in specific environmental contexts, and related it to sedentism and increased complexity among foragers (Rowley-Conwy and Zvelebil, 1989). In 2001, Rowley-Conwy expanded on the ‘variability’ concept regarding anthropological foragers and dealt with archaeological assumptions and misconceptions regarding hunter-fisher-gatherer complexity (Rowley-Conwy, 2001). In 2014, Rowley-Conwy followed an anti-progressivist thread and concluded that north European foragers were uninterested in the expanding farming lifestyle from the south, presenting evidence of the opposite and concluding that complexity and human adaptation do not follow a given path from simple to complex and mobile to stationary (Rowley-Conwy, 2014). He argues that Scandinavian foragers had the upper hand and that their level of environmental adaptation and societal complexity was responsible for the 1500-year halt of agricultural expansion (Rowley-Conwy, 2014). In 2016, Rowley-Conwy returned to the variability theme when he (and Stephanie Piper) discussed the degree of territoriality as a tool for understanding variations in complexity and delayed-return lifestyles, again drawing on analogies from the northern coasts of America and applying them to the archaeological record from, mainly, Scandinavia (Rowley-Conwy and Piper, 2016).

Another important publication concerning forager complexity is the volume edited by Douglas Price and James Brown (1985b), which set the stage for the recognition of complex foragers in archaeological contexts. Price follows on from the earlier discussions by Rowley-Conwy (1983) and discusses complexity among (Late) Mesolithic Scandinavian foragers (Price, 1985). The same publication also offers early evidence of Late Palaeolithic complexity on the central Russian plains (Soffer, 1985) and in France (Mellars, 1985), discussions of pre-agriculture sedentism among the Natufians in the Levant (Henry, 1985), and discussions concerning American north-west coast complexity (Ames, 1985; Hayden et al., 1985; Sheehan, 1985).

As illustrated by the above research, anthropological evidence from the American north-west coast has been paramount to the understanding of foraging complexity. For example, extensive feasting ‘potlatches’ among north-west coast native Americans were initially described by Boas in the late 19th century (Boas, 1897). Even though they were not linked to the modern definition of complex forager behaviour until much later, these early accounts enabled later researchers to theorize and link complex social behaviour with the ability to generate surplus and throw large feasts, and connect it to increasing levels of social stratification and societal complexity (Hayden, 1995). Furthermore, and related to the American north-west coast, in 2003 Fitzhugh followed temporal trends on Kodiak Island outside Alaska (Fitzhugh, 2003). By modelling the ‘evolution of complexity’ through means of optimal foraging, prey choice, environmental and aggregation theories, he suggests an increasing complexity as populations increase, locally depleting the most highly rated prey, and as technology advances to cope with the increasing population (Fitzhugh, 2003). Given that the end result is known, i.e. complex and densely populated societies prior to Russian contact, his model estimates increasing sedentism and complexity following a set of premises that need to be fulfilled. Fitzhugh does not, however, propose a linear development from simple to complex, and repeatedly states that complexity can both increase and decrease within a given timeframe. However, even though the archaeological record is far from perfect, especially among older sites, with mostly shallow surveys having been done and few complete excavations, Fitzhugh does suggest that the archaeological data support the model (Fitzhugh, 2003). Therefore, and despite faunal remains having been insufficiently recovered and analysed[12], indirect evidence supports his model and provides a focus of what to look for in the archaeological record in areas where complex foragers have not been ethnographically documented.

Point Hope, located more than 1300km to the north-west of Kodiak Island, in western Alaska, provides further evidence of variability among Alaskan forager complexity. Although the location has been known since the early 19th century, with various forms of ethnographic accounts of the whaling communities residing there at the time of European contact (Murdoch, 1892; Simpson, 1943), the first archaeological investigations did not occur until the mid-20th century (Larsen and Rainey, 1948). These excavations attracted the world's attention, and the ancient Inuit cultures became famous for their intricate artwork and elaborate artefacts. However, it was not until the latest publication in 2014, when all the evidence from the peninsula was combined and the whole variable spectrum of complex foragers prior to European contact examined (Hilton et al., 2014), that the possibility of foraging complexity taking many forms, depending on the mode of subsistence and varying life choices, could be truly considered.

3.2. Food and diet in Scandinavian Mesolithic

3.2.1. The (zoo)archaeological record

Even though numerous Mesolithic sites have been found throughout Scandinavia, most of them have not been thoroughly excavated or analysed, and only a precious few sites have organic remains that allow a closer study of diet and subsistence strategies. All known Mesolithic locations with favourable preservation are therefore highly important for palaeodietary and subsistence studies.

One of the first steps taken to address Scandinavian prehistoric forager diet was in 1848, when a group of Danish scholars was commissioned to investigate some of the known large Danish shell middens. This first Danish kitchen midden

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[12] Thus preventing a deeper understanding of the development and variability of the subsistence trends at Kodiak Island.

commission (køkkenmøddingkommission) concluded that the middens were food waste from old prehistoric societies (Forchhammer et al., 1851). At this time it was also recognized that the early 'savage' population in Scandinavia relied on hunting and fishing prior to the use of agriculture (Nilsson, 1866). Some years later, in the 1890s, a second kitchen midden commission was undertaken in Denmark, which, through a more multidisciplinary approach, investigated parts of a midden from the famous Ertebølle site on Jutland in Denmark (Madsen et al., 1900), where the zooarchaeological studies by Herluf Winge showed the incorporation of shellfish, fish and mammals in the diet. In the years following the second kitchen midden commission, Danish archaeologists unearthed a series of Early Mesolithic settlements with preserved organic material. The first site to be found was Mullerup (Sarauw, 1903), where Winge carried out the zooarchaeological analysis and showed the presence of fish, birds and carnivores, with ungulates dominating the assemblage. Next Sværdborg (Friis Johansen, 1919) and Holmegaard (Broholm et al., 1924) were found, both zooarchaeologically analysed by Winge and both sites showing roughly similar bone assemblages as Mullerup. All of these sites have been revisited for further or nearby excavation and/or complementary zooarchaeological analysis (Aaris-Sørensen, 1976; Becker, 1945; Brinch Petersen and Rosenlund, 1972; Henriksen et al., 1976; Nielsen, 1921; Rosenlund, 1971). The zooarchaeological analyses of these revisits were made by Kim Aaris-Sørensen and Knud Rosenlund but, although the analyses were closer to current standards, the methods of excavation were not fine enough to catch large amounts of fish bones and, correspondingly, the zooarchaeological analyses highlighted ungulate hunting. The bone assemblages from these sites have also been revisited by different researchers, e.g. Richard Carter (2001) and Charlotte Leduc (2012), who focused on different aspects of ungulate hunting. Although the Ertebølle site has been revisited and a large amount of Late Mesolithic sites related to the Ertebølle culture have been found, this thesis deals mainly with the Early and Middle Mesolithic. Therefore, Late Mesolithic sites will not be further explored, except when discussing developments in fish bone analysis. However, a recent study by Kurt Gron and Harry Robson (2016) is worth mentioning, in which they have compiled all the major known Danish Ertebølle sites with preserved bone material and some form of available zooarchaeological analysis reported.

To continue with the important Early Mesolithic sites, Lundby I and II, located close to the Sværdborg sites on southern Zealand in Denmark, should be mentioned. Lundby was initially found in 1929, but not comprehensively published until 1980, at that time including a zooarchaeological analysis by Rosenlund, in which he presents both number of identified specimens (NISP) and minimum number of individuals (MNI) and discusses seasonality as well as providing a rough account of the percentage of young animals from the most commonly occurring terrestrial mammals (Henriksen et al., 1980). Similar to the previously mentioned sites, the Lundby area has also been revisited (Møller

Hansen, 2003; Møller Hansen et al., 2004) and reanalysed (Leduc, 2014) since the initial excavation of the first of a number of sites. Because of the nature of the later excavations, the discussions of these sites centred on elks (*Alces alces*), mainly based on the zooarchaeological analysis by Aaris-Sørensen (Møller Hansen, 2003; Møller Hansen et al., 2004). In the mid-20th century, the Kongemose (Jørgensen, 1956) and Ulkestrup Lyng (Andersen et al., 1982; Richter, 1982) sites were found and excavated. While the initial zooarchaeological analysis of Ulkestrup Lyng was made by Jane Richter, both sites were later revisited by Nanna Noe-Nygaard (1995) for extended zooarchaeological analysis, which focused on traces of human activity visible on terrestrial mammal bone remains. In 1956, one of the first submerged sites to be encountered, the site of Argusgrunden, was found while pumping sand from the seabed. Argus was investigated in 1984 by a team of divers and, while most of the finds had been pumped to the surface, thus preventing stratigraphic orientation, some features, e.g. a hearth, were removed in blocks. The zooarchaeological analysis was made by Ulrik Møhl (1987), which, because the majority of the recovered bones represented red deer, roe deer (*Capreolus capreolus*) and wild boar, centred on their remains. It was, however, recognized that fish would probably have been more important than the zooarchaeological remains indicated (Fischer et al., 1987:47), based on a perceived large taphonomic loss as a result of the recovery methods implemented and because of preservation issues related to fish bones. In addition to the analysis of the Argus bone remains, Møhl has analysed the bone remains recovered from the Early Mesolithic sites of Skottemarke, Favrbo, Mosegården, Flaadet and Verup, all of them indicating a focus on ungulates (Møhl, 1961; 1978; 1979; 1984).

The Late Mesolithic site of Soldattorpet from Limhamn (Malmö) in south-western Sweden is one of the earliest Mesolithic coastal sites to have been subjected to an archaeological excavation (Kjellmark, 1903). However, Mesolithic sites were known at that time from a number of locations in southern Sweden (Kjellmark, 1904), even though it was somewhat difficult to place all of the sites in a chronological order. In the late 19th century the area around Lake Ringsjön in Scania became known for its large numbers of Mesolithic finds from around 20 different sites, which were thought to harbour a substantial volume of different material from the oldest period (Hildebrand, 1883; 1886; Kurck, 1872; Reventlow, 1905).

The first Mesolithic site in the Ringsjön area to be archaeologically excavated was Ringsjöns utlopp, which was excavated in 1886–87 and a zooarchaeological analysis made by August Quennerstedt (Reventlow, 1886; 1889). Ringsjöns utlopp had been found 4 years prior to the excavation as a result of the lowering of the water level in Ringsjön in 1882–83. At the same time as Ringsjöns utlopp was found, the site Sjöholmen was encountered on the opposite side of the Rönne stream. Although initially found in connection with the lowering of the water level of Ringsjön (Reventlow, 1889), the site appeared to have been largely forgotten until 1925, when a drainage system was dug next to the railway and worked flint, ceramics and bones were found, which led to initial excavations in 1929 and 1930 (Forssander, 1930; Rydbeck, 1930) and a revisiting of the site in 1950 (Thomas, 1954) and 1961. However, Sjöholmen was, similar to Ringsjön utlopp, mixed with finds from a Neolithic settlement at the same location, which makes zooarchaeological interpretation difficult. Nevertheless, attempts at a zooarchaeological analysis were made on the palimpsest of bone material from the 1961 excavation by students in historical osteology at Lund University (Brännborn et al., 2008).

An undisturbed and non-conglomerate Middle Mesolithic settlement with preserved organic remains was first encountered in Segebro in 1935 (Kalling, 1936), although finds were scarce from this initial excavation and it was not until the 1960s, when a new excavation was conducted, that a more thorough picture of the settlement could be made, which included finds from a late-glacial settlement located beneath the Mesolithic layers (Salomonsson, 1960; 1962). Segebro was excavated again on three different occasions in the 1970s, and published in 1982 (Larsson, 1982). The 1982 publication included a zooarchaeological analysis of the completely recovered bone material by Johannes Lepiksaar, and he showed a high species diversity including many coastal species, such as seals, porpoises, different birds and both marine and freshwater fish. However, the main bulk of the diet was interpreted to have come from red deer, wild boar and roe deer.

Between the first and the second excavations at Segebro, the first Ageröd sites, in central Scania, had been excavated between 1946 and 1949 by Althin (1954), with the initial zooarchaeological analysis work carried out by Herved Berlin (although he died before his results were published). Since the first excavation and publication, Ageröd has been revisited, in 1972–74 and again between 1978 and 1980, with the results published some years later (Larsson, 1978a; b; 1983; Larsson et al., 1981). The publications on the Ageröd sites also included zooarchaeological analyses by Lepiksaar, where he indicated the number of fragments from each species found and provided rough estimations of the minimum number of individuals, along with presenting the determinations made by Berlin prior to his death. Lepiksaar leaves most of the interpretations to Lars Larsson, who in turn focuses mostly on the dietary yields of the terrestrial mammals (highlighting ungulates), albeit while mentioning that fishing was probably more important than can be seen in the bone assemblage, based on the location of the Ageröd sites.

The next site to be located in Sweden was Bua Västergård on the Swedish west coast, which was excavated in 1970 and fully published 13 years later (Wigforss, 1983), with the zooarchaeological analysis carried out by Lepiksaar and interpretations similar to those regarding Segebro. In the beginning of the 1980s, excavations were carried out around Lake Hornborgarsjön, and one of the sites located and excavated there was Almeö (Kindgren, 1983; 1995); although a zooarchaeological analysis was not included in a comprehensive publication, Agneta Arnesson-Westerdahl did analyse the recovered bone material (Arnesson-Westerdahl, 1984). The Almeö site is the oldest Early Mesolithic settlement site in Sweden with preserved organic remains and, like the interpretation of other Early Mesolithic sites, the hunting of ungulates, especially aurochs (*Bos primigenius*), dominates the discussions. However, similar to Larsson's view regarding fish at Ageröd, Arnesson-Westerdahl believes that fish would have been an important food source, basing her arguments on the large amounts of recovered fish bones (651 identifiable fish bones) from all areas of the excavation, despite poor preservation on the site. In 1989 the Middle Mesolithic site of Hög was excavated in mid-Scania in southern Sweden, with zooarchaeological analyses by Elisabeth Iregren and Lepiksaar (1993), the results of which highlight a nutritional basis from red deer, roe deer and wild boar and from 'aquatic' resources of beaver (*Castor fiber*). Fish bones are present; however, even though the site was sieved (with an unspecified mesh size or method), few bones were recovered (the number unspecified) and only from freshwater species. During the same year that Hög was excavated, the site of Ringsjöholm, located close to Sjöholmen, a small distance from the Ageröd sites, was discovered by Arne Sjöström and excavated between 1994 and 1996 (Sjöström, 1997). The zooarchaeological analysis was done by students in historical osteology at Lund University (Jansson et al., 1998; Pedersen et al., 2005; Svensson, 2006), and they focused on different aspects of Middle Mesolithic subsistence.

Around the time that Ringsjöholm was found, the site of Huseby Klev was discovered on the Swedish west coast on the island of Orust. The site was excavated in 1992–94 with a report published 11 years later (Nordqvist, 2005). The report included a brief zooarchaeological analysis by Leif Jonsson, where he listed the species he could observe from the different phases of the site's occupation. Because this analysis was not comprehensive, a thorough analysis was made by bachelor degree students in historical osteology at Lund University (Christensson, 2015; Hellgren, 2015; Nemecek, 2015; Widmark, 2015), with their quantifications later used to interpret the site and put it within the contextual framework applied in this thesis (paper IV). A few years later, also on the Swedish west coast, the site of Balltorp was excavated and the zooarchaeological analysis published by Jonsson (Jonsson, 1996). The location was excavated again in 2008 (Johansson, 2014), once more with Jonsson in charge of the zooarchaeological material. Although the recovered bone material from both excavations was small, they both included ungulates, seals, fur game, birds and fish in the bone assemblages. In 1993 the site of Rönneholms mosse was discovered in the Rönneholm bog, located close to the previously discussed Ageröd sites, in central Scania. Rönneholms mosse was initially excavated in 1995 (Sjöström, 1995) and has been revisited on a number of occasions since then, as new settlements have been located during the ongoing peat extractions in the area (Hammarstrand

Dehman and Sjöström, 2009; Sjöström, 2004; 2013). The zooarchaeological analyses of the bone material from Rönneholms mosse have been done by Magnell (2010; 2011), who focused on terrestrial mammals, mostly on ungulates and dogs (*Canis familiaris*), because of the small quantities of fish and bird bones in the bone assemblage. The last important Early or Middle Mesolithic site to be recovered in southern Sweden is Tågerup, located on the west coast of Scania. This site was excavated with varying intensity between 1995 and 1998 (Karsten and Knarrström, 2003) and subjected to a broad spectra of varying types of analyses, among which zooarchaeological studies were included, carried out by Mats Eriksson and Magnell (2001). The zooarchaeological analysis revealed a large species diversity, including a large amount of terrestrial mammals, aquatic mammals, fish and birds. The bone material has been interpreted as showing a larger dietary importance of terrestrial species in the earliest phase, although marine fish was considered important here as well, followed by a temporal increase in fish dependency[13]. Aquatic mammals, though present, were interpreted to have been of lesser importance throughout all phases of occupation (Eriksson and Magnell, 2001).

On the island of Gotland, in the Baltic Sea, the first indications of Mesolithic occupation are related to the extensive archaeological investigations carried out between 1888 and 1893 by Lars Kolmodin and Hjalmar Stolpe in the Stora Förvar cave on Stora Karlsö on the west coast. The results, however, were not published until 1940 (Schnittger and Rydh, 1940), although the zooarchaeological analysis had been published 14 years earlier by Adolf Pira (1926) focusing on different aspects of seal hunting, with expanded interpretations made 20 years later by Grahame Clark (1946; 1976). The cave has since been revisited and reanalysed on a number of occasions, e.g. Christian Lindqvist and Göran Possnert (1999) and Jan Apel and Jan Storå (2017), with additional zooarchaeological analyses being carried out by both Lindqvist and Storå. In 1909 the Middle Mesolithic site of Svalings was located by Hjalmar Olsson, during a geological survey (Nihlén, 1927). The few bones recovered from the site were determined to be seal, with the addition of a human skull fragment, which have since then been lost (Andersson, 2016; Lindqvist and Possnert, 1997). In 1928 the site of Gisslause was found and it was excavated a year later (Munthe and Hansson, 1930). Gisslause was revisited in 1982 (Burenhult, 1999; Seving, 1986) and again in 2013 (Apel and Hongslo Vala, 2013). Three additional Mesolithic sites from the earliest phase on Gotland, with preserved bone remains, are worth mentioning. These are the Strå settlement found in 1935 and excavated by Stenberger, with later zooarchaeological analysis by Lindqvist (Lindqvist and Possnert, 1997), the Kambs Lummelunda double grave excavated by Stenberger in 1939 (Stenberger, 1939), and the Stora Bjärs

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[13] The importance of fish was further illustrated by a large stationary fishing weir and the numerous fish traps recovered at the site (Mårtensson, 2001).

grave, which was found in 1954 during the excavation of a Bronze Age site (Arwidsson, 1979; Lindqvist and Possnert, 1997). In recent years Apel and Storå have also published papers on both the Mesolithic and later phases of Gotland prehistory (Apel and Storå, 2017; Apel et al., 2017).

Apart from the studies related to specific sites and particular investigations, there are other authors and publications worth mentioning. For example, Magnell, who in 2006 published his dissertation on wild boars, has greatly improved our understanding of Mesolithic wild boar hunting strategies and prey choice (Magnell, 2006). Carter (2001), Rowley-Conwy (1993) and Magnell (Submitted-b) have all addressed, through zooarchaeological analyses, the issues of inland seasonal occupation of Mesolithic sites. Hans Peter Blankholm has attempted to integrate the zooarchaeological record (especially the terrestrial mammal remains) into an interpretation of the Maglemose culture (Blankholm, 1996), and Hein Bjerck has, through a number of investigations and analyses, studied and discussed Mesolithic subsistence on the west coast of Sweden and Norway (Bjerck, 1994; 2007; 2009; 2016).

3.2.2. Fish bone analysis

A fish bone analysis was first carried out on Scandinavian Mesolithic bone material in the mid-19th century, when Japetus Steenstrup analysed the bone remains recovered from the first kitchen midden commission in Denmark (Steenstrup, 1862:12-13). This was followed by a small-scale analysis of the fish bones from Ringsjöns utlopp by Quennerstedt (Reventlow, 1886; 1889). However, even though some fish bones were found and species determinations were made from most of the early recovered Mesolithic sites with preserved organic material, they were too few[14] to raise an awareness of the potential in fish bone analyses[15]. Therefore, and despite discussions highlighting fish in the diet of both Late Palaeolithic and Early Mesolithic humans (Clark, 1948), it was not until well into the second half of the 20th century that a number of publications highlighted the use of ichthyo-archaeological studies when interpreting archaeological remains (Casteel, 1972; 1974; 1976a; b; Wheeler, 1978). More locally, qualified fish bone analyses, as with so many other things related to Scandinavian zooarchaeology, can be traced back to the works of Lepiksaar. As the main zooarchaeologist working during the initial recovery boom of Mesolithic settlements, he analysed fish bone remains from, among other places, Bua Västergård (Lepiksaar, 1972;

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[14] Wet sieving was not applied at any of the early excavations, thus fish bones would have been missed.

[15] This, in turn, contributed to a focus in discussions on terrestrial mammal subsistence and hunting strategies in much of the previous Early Mesolithic research (cf. The (zoo)archaeological record, Chapter 3.2.1).

1983b), Ageröd (Lepiksaar, 1978; 1983a) and Segebro (Lepiksaar, 1982). He also compiled the *Osteologia Pisces* fish bone compendia, of which different versions have been circulated among ichthyo-archaeologist since the beginning of the 1980s (Lepiksaar, 1994). Lepiksaar concluded his work on fish bone analysis by publishing the faunal history of freshwater fish in Sweden, which was based on all, at the time of writing, available subfossil finds from Sweden (Lepiksaar, 2001) and became available 4 years prior to his death. His work, together with more standardized methods of measuring fish bones (Morales and Rosenlund, 1979) and the thorough review of fish bone analysis by Wheeler and Jones (1989), established fish bone analyses as an important part of any archaeological investigation.

If Lepiksaar can be considered one of the pioneers in Mesolithic fish bone analysis, Inge Bødker Enghoff can be said to have done most of the work related to archaeological fish bones, not only for the Mesolithic period but for all time periods, in Scandinavia. Her work on Ertebølle sites is incomparable and her work on a large number of sites has certainly provided good evidence of the importance of marine resources to Late Mesolithic human populations in southern Scandinavia (Enghoff, 1987; 1989; 1991; 1994; 1995; 2011; Enghoff et al., 2007).

Because of the site's importance for discussions on complexity among Scandinavian foragers, the Late Mesolithic site of Skateholm, for which Jonsson did the zooarchaeological analyses, should be mentioned in particular. This site has, in many regards, come to stand as a good example of the territorial displays shown by Scandinavian foragers, because of the location and visibility of the large cemeteries associated with the site (Larsson, 1988a; b; 1989; 1993). Furthermore, it is one of the first Late Mesolithic sites in Sweden, that, similar to many of the Danish contemporaneous sites, came to be known for its large amount of fish bone and thus to provide a good indication of aquatic subsistence strategies in a society associated with territorial displays. Interestingly, and perhaps not given enough consideration, the fish bone assemblage from Skateholm consists mostly of freshwater fish, in both the cultural layer and in the graves (Jonsson, 1986; 1988), even though the site is located in a marine/brackish water environment[16].

Some additional scholars have been involved in large Scandinavian fish bone analyses from forager contexts. Because of their contribution to the field, Annica Cardell (2004), Jan Ekman (Ekman, 1974), Per Ericson (1994; Knape and Ericson, 1983; Segerberg, 1999), Noe-Nygaard (1983), Carina Olson (2008), and Kenneth Ritchie (et al.) (2016; 2010; 2013) should be specially mentioned.

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[16] Albeit in a lagoon close to the outlet of a freshwater stream.

3.2.3. The use of stable isotopes in Mesolithic research

In Scandinavian Mesolithic research, Henrik Tauber was the first to recognize the potential of using stable isotopes when studying human diet. In the early 1980s, he was able to show high $\delta^{13}C$ values in Late Mesolithic human remains (Tauber, 1981), which correlate with a predominantly marine diet. High (less negative) $\delta^{13}C$ values in human collagen is dependent on the consumption of C_4 plants (plants that produce a four-carbon molecule and follow the Hatch–Slack pathway when fixating carbon in photosynthesis (Slack and Hatch, 1967)), as opposed to the C_3 plants (plants that produce three-carbon molecules and follow a Calvin–Benson carbon fixation pathway (Calvin and Benson, 1948)). High $\delta^{13}C$ values in human collagen is also caused by a subsistence based on marine resources (because $\delta^{13}C$ is enriched by submerged absorption of carbon dioxide and consequently the photosynthesis by aquatic plants produces elevated levels of $\delta^{13}C$ compared with terrestrial C_3 plants). As no major edible C_4 plants (such as maize (*Zea mays*), sugar cane (*Saccharum officinarum*) and millet (Poaceae)) are native to Scandinavia, the elevated $\delta^{13}C$ values observed in the Late Mesolithic human remains prove the importance of marine resources to the Late Mesolithic Scandinavian societies. Tauber's work was followed by Noe-Nygaard (1988), who studied Mesolithic and Neolithic dogs and concluded that dogs and humans had a similar diet, in addition to showing a distinct decrease in marine food in the Neolithic period compared with the Late Mesolithic.

Since Tauber's use of $\delta^{13}C$ in human collagen, $\delta^{15}N$ has been introduced as a different marker for studying bone chemistry. Nitrogen can be used similarly to carbon, i.e. as a means to study diet. However, whereas carbon in bones is a reflection of the dietary source from the living environment and its pathway through photosynthesis, nitrogen is mainly used to measure the trophic level of the studied specimen (Minagawa and Wada, 1984; Wada, 1980). Therefore, human collagen $\delta^{15}N$ values indicate what trophic level the main/average prey of that human occupied and, as marine food chains are longer than terrestrial food chains, the consumption of fish results in more elevated $\delta^{15}N$ values (Schoeninger and DeNiro, 1984).

One of the first to study isotopes in Scandinavian Mesolithic remains was Kerstin Lidén, who presented her thesis in 1995, in which she included a small sample of Late Mesolithic human isotope values from Skateholm, in Scania, southern Sweden, as well as two samples from Kambs Lummelunda, from the island of Gotland in the Baltic Sea (Lidén, 1995; 1996). Similar to Tauber, she concluded that the Late Mesolithic populations were heavily dependent on marine resources. Furthermore, she suggested that the two individuals from Gotland might have been eating freshwater fish from lakes and/or fish from the Baltic Sea. Eight years after Lidén, Gunilla Eriksson published her thesis, in which she studied Stone Age isotopes (Eriksson, 2003). Her study was broad and she examined the mobility and diet of individuals from the Mesolithic and the Neolithic in both southern Sweden and Latvia. Of special interest to this thesis is the work of Eriksson and colleagues on some of the individuals from Huseby Klev, who they determined had been highly focused on marine subsistence, and an individual from Hanaskede, in Västergötland, Sweden, who they interpreted as having somewhat changing isotope signals throughout life, with a primarily terrestrial diet during the last 10–15 years and somewhat more marine during the early years of life. Lastly, the isotope signals from some of the Ageröd individuals are of interest: they suggest that terrestrial resources had dominated the diet but that one of the individuals might have had a large input from freshwater fish or to have hunted grey seals on the east coast of Sweden (Eriksson, 2003; Lidén et al., 2004).

Four years after Eriksson's thesis, the next major isotope paper was published by Anders Fischer and colleagues (2007). Here the authors presented and examined a large number of Danish human isotope samples from both the Mesolithic and Neolithic periods and concluded that there was a strong reliance on aquatic resources in both Middle and Late Mesolithic humans, as well as suggesting a high degree of coast to inland mobility, although the latter interpretation comes with a warning because of problems with the freshwater fish showing baselines that overlapped both marine and terrestrial resources. Since Fischer et al. (2007) published their paper, no broad syntheses have been attempted to, by means of stable isotope analysis, investigate general human subsistence trends during the Early and Middle Mesolithic. However, many 'less synthetic' investigations focusing on the isotope signals from a limited number of sites can be mentioned, as their results add to the available stable isotope data set (Borrman et al., 1995; Eriksson et al., 2016; Fornander, 2011; Robson et al., 2012; Robson et al., 2016; Sjögren and Ahlström, 2016; Sten et al., 2000).

4. Theoretical perspectives

Zooarchaeological theory is often situated within an archaeological context and generally follows the broader 'mother' discipline to a certain degree. However, zooarchaeology is working with organic perishable materials, and as such understanding taphonomy has come to play an increasingly important role over the last 40 or so years (Lyman, 1994). Taphonomy deals with the path from the living community, 'biocoenos', to the death community, 'tanatocoenos', and the biases following the death community inherent in what is left to interpret. Taphonomy was originally defined as 'the study of the transition (in all its details) of animal remains from the biosphere to the lithosphere' (Efremov, 1940). In zooarchaeology, taphonomy begins with the conscious human choice of killing an animal and ends when the final word has been written about the material in question (Fig. 2).

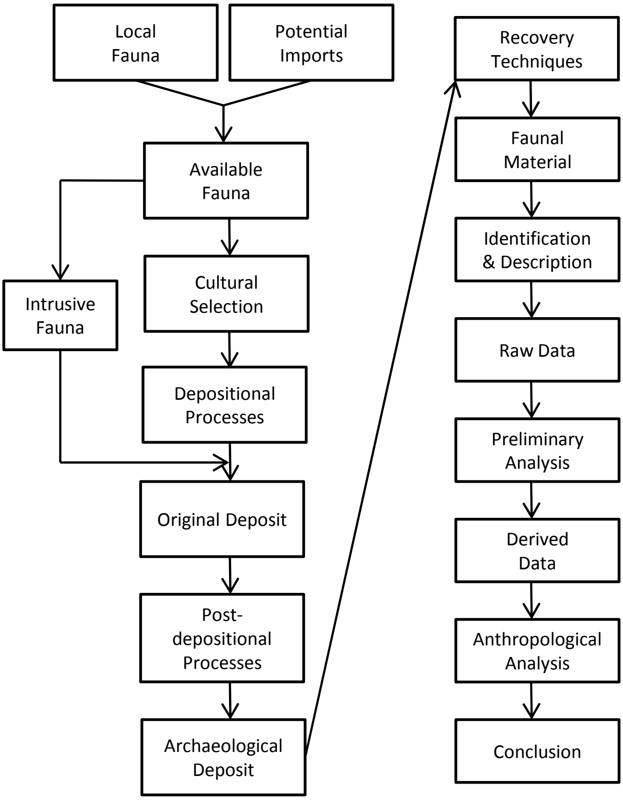

Figure 2 The taphonomic process according to Medlock (1975).

Taphonomy can be seen as the most fundamental theoretical framework for osteoarchaeological studies, and very few, if any, zooarchaeological analyses or interpretations carried out today are done without any reflection of how time, soil conditions, methods of excavation, post-depositional disturbances, carnivore gnawing, exposure before coverage, human rituals, etc., have affected the material. Consequently, it has been suggested that 'Close attention to taphonomic detail through structures analysis...is vital…to move beyond the superficial and speculative'(Orton, 2012:335).

When interpreting bone assemblages it is important to recognize the full spectra of taphonomic histories that have led to the recovered deposition of a material, and that many different actions, strategies and taphonomic histories can lead to similar archaeological remains, i.e. the problems associated with equifinality must always be considered (Lyman, 1994:38). Furthermore, bones not only represent the remains of a meal or a successful hunting or fishing trip, but encompass a wider spectrum of plausible origins. Therefore, it is important to not let interpretations become inappropriately narrowed 'by seeing the animals only in terms of protein and calories' (Russell, 2011:7). Animals fulfil a wide range of roles in human societies, e.g. as objects of admiration, wealth, symbols, pets, feasting, sacrifice, raw materials, etc., all of which can have an impact on the content of the bone assemblage in question.

Today, zooarchaeologists generally agree that the actual bones themselves hold a certain degree of 'objectiveness' in terms of identification to species, sex, age, size, etc. (although this objectiveness is often dependent on the methods used for deriving the sex, age and sometimes even species information), which is not as easily determined for archaeological artefacts. As such, zooarchaeological research is considered here to be able to deliver objective interpretations.

In this thesis an interdisciplinary approach is taken, while aiming for holistic interpretations. In certain areas processual reasoning has been used, fitting archaeological data into ethnographic, environmental, biological, quaternary geological, ecological and sociological frameworks, which combined enable interpretation of the data. However, efforts have also been made to clarify cases where objective or interpretative deductions cannot be made. This is especially true when certain contextual key evidence is lacking; because of the nature of the archaeological record, where the requisite data cannot be found, consequently conclusions cannot always be reached. In addition, it should be acknowledged that even in cases where 'all' key evidence is present, objective interpretations cannot always be made, either because the evidence is dependent on the methods applied in gathering the data, therefore biasing the interpretations, or because the societies being studied differ too greatly from our current research horizon, such that certain areas/interpretations remain out of reach.

Is it then possible to choose between different interpretative frameworks when carrying research, and does it not border on heuristic use of analogies to further one's own interpretations and subjective views? All research must use a framework that fits the applied method. This implies that, while choosing a method to work with is essential for all science, its application not only enables a certain framework of interpretations, but also limits the possible output. Here an eclectic approach[17] has been used, in an attempt to incorporate different perspectives when trying to solve the prehistoric puzzle at hand. This has several implications. First of all, the fundamental view in this thesis is that it is possible to deduce valid acquiescent interpretations of past societies or events, e.g. that bone materials can be used to deduce information[18] about subsistence strategies, diet, health, seasonal occupation, environment, mobility climate, etc. However, it is also acknowledged that some interpretations are coloured by a subjective perspective stemming from the interpreter's personal experiences, cultural and social background. Furthermore, interpretations of any archaeological material also stem from a diverse set of human societies, each with their own way of dealing with both the profane and the mundane. Therefore, all archaeological remains have passed through cultural filters[19] and, consequently, the interpretations of an archaeological assemblage must consider and relate to the variability of cultural expressions, which is no easy task given that the investigated societies are long gone and the scattered archaeological remains are all that is left of them.

In order to cope with all the different factors that can hinder an objective interpretation of past societies, different aspects of an interpretation must be compared to deliver the most likely explanation. In archaeology, chronology and the ability to put the remains within a contextual framework is often the starting point for all research, whereby dating, stratigraphic information and diagnostic artefacts are essential to enable interpretations of a specific time period or culture. In this thesis, the framework encompass the two earliest periods in post-glacial southern Scandinavia, i.e. the Early and Middle Mesolithic period, dated to around 11,500–7500 cal. BP. The archaeological cultures in focus are the Early

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[17] Here referring to selectively choosing the methods deemed best to answer the relevant questions.

[18] Thus it is important to note that bone material is the accumulated remains from many different processes and, while information can be deduced from it, it must also be acknowledged that it does not represent the unaltered 'proof' of a group's diet, health, mobility, seasonality or climate, etc. Instead they must be considered within the framework of cultural filters and taphonomic processes.

[19] In other words, the belief system of a particular group of people can determine what is considered to be everyday food, food for feasts, sacrificial food, appropriate or allowed food. Furthermore, a taboo on certain animal (or plants) species might exist (during certain months, for certain members of a group, or a total taboo), and the food culture of a group can dictate what is considered to be edible, nutritious and tasty. In addition, current methods of both archaeological excavation and analysis act as a 'modern' filter on the investigated subject, which also affects the interpretations.

Mesolithic Maglemose culture and the Middle Mesolithic Kongemose culture[20]. In terms of diagnostic 'key type' artefacts and the identification of the cultures, this typically includes flint handle cores, slotted bone points and daggers and microliths, with a temporal transition from lanceolate microliths to scalene triangular microliths to trapezoid microliths during the Early to the Middle Mesolithic period. The flint-knapping techniques also undergo a temporal transformation, with the direct techniques dominating the first two millennia of the Early Mesolithic being replaced in the late Maglemose culture (around 9500–9000 cal. BP) by indirect pressure blade technology[21] (Sørensen, 2012). The pressure blade technique then undergoes a temporal improvement, and an improved blade technique appears over large areas in the transition from the Maglemose to the Kongemose culture, resulting in higher frequencies of large flint blades during the Middle Mesolithic period (Sørensen, 2017).

In this thesis the archaeological explanation models often revolve around abductive methods[22] (Cartwright and Montuschi, 2014; Okasha, 2016), judging between multiple possible interpretations or explanations to deliver an interpretation based on the 'best' explanation given what is currently known, or with the use of currently available methods applied to the currently known materials. Therefore, even if it can be said that archaeological research often starts with an inductive method approach, e.g. observations and data collection start with the excavation, the abductive approach taken her, i.e. using inference to best explanation models (IBE) (Okasha, 2016), should be considered as offering a hermeneutic perspective. An abductive approach also works well when considering different taphonomic histories of bone assemblages, and can facilitate deciphering of the most likely scenarios resulting in the observed bone assemblage in question. IBE models can also be used as a tool to compare different materials that, given the nature of archaeological organic remains, can never (or extremely rarely) be considered to have the exact same taphonomic history.

During the course of the work on this thesis, IBE has frequently been used to interpret the data. For example, in paper I, when reaching the conclusion that fish had been fermented at the site, different observations were compiled and, in trying to explain them all, an IBE model was used. Put another way, there were many available explanations for each of the many observations made concerning the fish fermentation pit, but the best explanation generated a conclusion including all of the observations. Thus the best explanation was that the fish had been fermented and stored for later use. Similarly, IBE was also used in paper V to provide the best explanation of why the human bones appeared to be older than all the other

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[20] And the Hensbacka and Sandarna cultures on the west coast of Scandinavia.

[21] Except on Gotland, where direct flint-knapping techniques prevailed and indirect techniques never became common practice (Apel and Storå, 2017).

[22] Although not always explicitly stated as such (within the different papers).

organic material. However, even though an IBE model was used, an initial hypothesis was made and an inductive quantitative approach also applied in paper V, regarding the fish bone quantification and preservation.

Paper III dealt with taphonomy and fish quantification using a more inductive approach, drawing generalized conclusions from the collected material. An inductive approach could also be said to have guided the writing of paper IV, regarding the bone material from Huseby Klev. However, even if paper IV started with an inductive approach, many of the conclusions were, similar to papers I and V, drawn using an IBE model. In paper II, a more hypothetical approach (Okasha, 2016) was used: a hypothesis regarding low residential mobility was made and tested against what could be observed in the bone material from Norje Sunnansund. Lastly, paper VI used a hypothetical method. An initial hypothesis regarding the importance of freshwater fish, specifically cyprinids (Cyprinidae), was the incentive for gathering data[23]. By collecting data and considering dietary sources based on the hypothesis, fish were shown to have a more important role in the human diet at a more general level.

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[23] Freshwater fish, especially cyprinids, had, prior to the analysis of the Norje Sunnansund fish bone assemblage, seldom been considered an important dietary resource in Scandinavian foraging contexts, thus this hypothesis would have been unlikely prior to the Norje Sunnansund excavation.

5. Material

This thesis consists of six papers dealing with different aspects of subsistence strategies and human life during the Early Holocene (11,500–7500 cal. BP), using a broad range of Early and Middle Mesolithic archaeological data from many different south Scandinavian archaeological sites (Fig. 3).

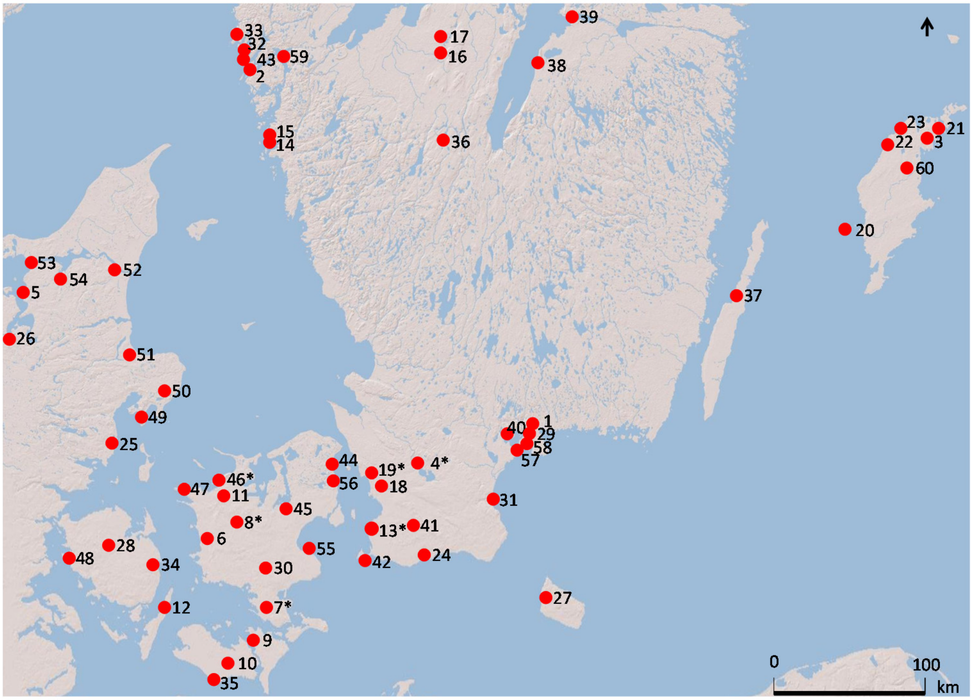

Figure 3 The Scandinavian Mesolithic sites used in the thesis; * indicates multiple sites at a location. 1=Norje Sunnansund; 2=Huseby Klev; 3=Gisslause; 4=Ageröd, Ringsjöholm, Ringsjöns utlopp, Rönneholms mosse, Sjöholmen; 5=Ertebølle; 6=Mullerup; 7=Sværdborg, Lundby; 8=Ulkestrup Lyng, Kongemose, Verup, Mosegården, Tømmerupgårds mose, Muldbjerg, Præstelyngen, Storelyng; 9=Argus; 10=Skottemarke; 11= Favrbo; 12=Flaadet; 13=Segebro, Soldattorpet, Malmö C, Malmö Harbour; 14=Bua Västergård; 15=Balltorp; 16=Almeö; 17=Hanaskede; 18=Hög; 19=Tågerup, Saxtorp; 20=Stora Förvar; 21=Strå; 22=Kambs Lummelunda; 23=Stora Bjärs; 24=Skateholm; 25=Norsminde; 26=Krabbesholm; 27=Ålyst; 28=Koelbjerg; 29=Lussabacken Norr; 30=Holmegaard; 31=Haväng; 32=Österöd; 33=Skibevall; 34=Sludegårds bog; 35=Syltholm; 36=Bredgården; 37=Övre Vannborga; 38=Alvastra; 39=Motala; 40=Barum; 41=Bökeberg; 42=Måkläppen; 43=Uleberg; 44=Nivågård; 45=Blak; 46=Bøgebjerg, Dragsholm; 47=Asnæs Havnemark; 48=Tybrind Vig; 49=Vængesø; 50=Nederst; 51=Dyrholm; 52=Havnø; 53=Bjørnsholm; 54=Hedegård; 55=Køge Sønakke; 56=Vedbæk; 57=Årup; 58=Ljungaviken; 59=Timmerås; 60=Svalings. Original map by Anders Edring.

While this thesis deals with southern Scandinavia, it is apparent, looking at Fig. 3, that a large area of southern Sweden has not been included, i.e. the counties of Småland and Halland. This is of note, but has a rational explanation. There are simply no Early or Middle Mesolithic archaeological sites with preserved organic material from these areas[24]. However, this does not mean that these areas were unoccupied during the Early Holocene. There are numerous Mesolithic finds from these counties, especially in areas around the lakes and rivers, e.g. in the area around the ancient lake of Bolmen (Fig. 4) and Åsnen and along the river systems of Nissan and Mörrumsån (Ameziane, 2009; Hanlon and Prahl, 1998; Persson, 2012; Taffinder, 1982; Westergren, 1979). Furthermore, even though most of the Early Holocene sites from, e.g., inner Småland have been interpreted as short-term settlements because of the low number of large knapping locations (Persson, 2012), some Early Mesolithic sites from inner Småland, e.g. Anderstorp and Nennesmo (Gustafsson, 2008; Pagoldh, 1995), have yielded large amounts of flint and have been interpreted as long-term, even all-year around, settlements, based on the recovered flint material, e.g. Nennesmo (Ameziane, 2009; Gustafsson, 2008).

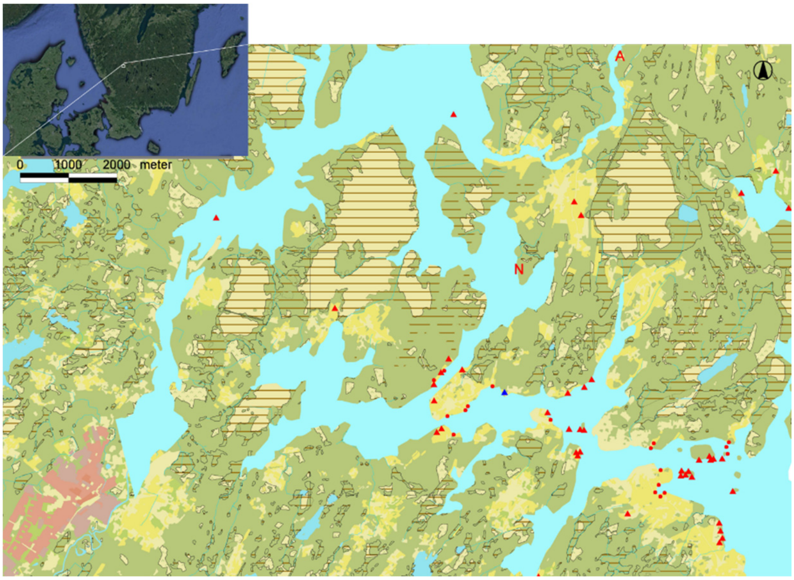

Figure 4 The location of Mesolithic sites in a small area of Småland, the area around the ancient lake of Bolmen (with its Mesolithic shoreline displacement). Triangles indicate settlements, dots indicate loose finds, N stands for the Early Mesolithic site Nennesmo and A for the Early Mesolithic site Anderstorp. Originally published in Ameziane (2009). Map by Jörgen Gustafsson, © Jönköpings County Museum. Top left: Google Earth 2017 (Data:SIO, NOAA, U.S. Navy, NGA, GEBCO).

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[24] One exception is the Middle to Late Mesolithic site of Järnsjön in Hultsfred municipality, where a small amount of bones has been recovered and both red deer and pike have been identified (Rosberg, 1994).

There are other reasons for the low number of Early Holocene sites recorded in these areas. Firstly, there is a strong correlation between the discovery of new sites and the area of arable land; as most of Småland is forested, the area is more difficult to survey and, consequently, it is more difficult to discover sites. Secondly, there is no naturally occurring flint in these areas, although quartz does exist and is frequently used; therefore the flint-knapping techniques have likely been economic in character. Economic flint-knapping techniques generate small amounts of waste, and sparse find material renders archaeological sites even more difficult to locate. The lack of naturally occurring flint can be advantageous for locating sites, as flint of anthropogenic origin cannot then be confused with naturally occurring flint. However, the chances of locating archaeological Mesolithic sites without excavation have probably limited the amount of sites actually excavated, and the generally low level of recent exploitation, i.e. a relative low degree if erecting new roads and buildings, in these areas means that few Mesolithic sites there have been subjected to a proper archaeological excavation. Lastly, and the reason why even the known sites from these areas have not been included in the thesis, poor preservation, as a result of leached acidic soil, has deprived the sites of organic remains, and they have therefore never attracted the same amount of attention as, e.g., the finds from Scania or Zealand.

Focusing on the sites with organic remains that have been investigated, there are three central sites/areas, Norje Sunnansund, Huseby Klev and Gisslause/Gotland, while an additional 44 sites have been used extensively, mainly in paper VI. In addition to this, a supplementary 30 Mesolithic sites have been used to frame the discussion and build some of the arguments and put them into context (for all the sites used in the thesis, see fig. 3).

5.1. Site descriptions

The main site, Norje Sunnansund (papers I–III), is located to the north of Sölvesborg in Blekinge, south-eastern Sweden (Fig. 5 left). The site is dated to between 9600 and 8600 cal. BP, although the actual period of occupation should be considered shorter because of calibration plateaus during the time period and because the carbon in the collagen was not optimally preserved, thus giving rather wide dating spans.

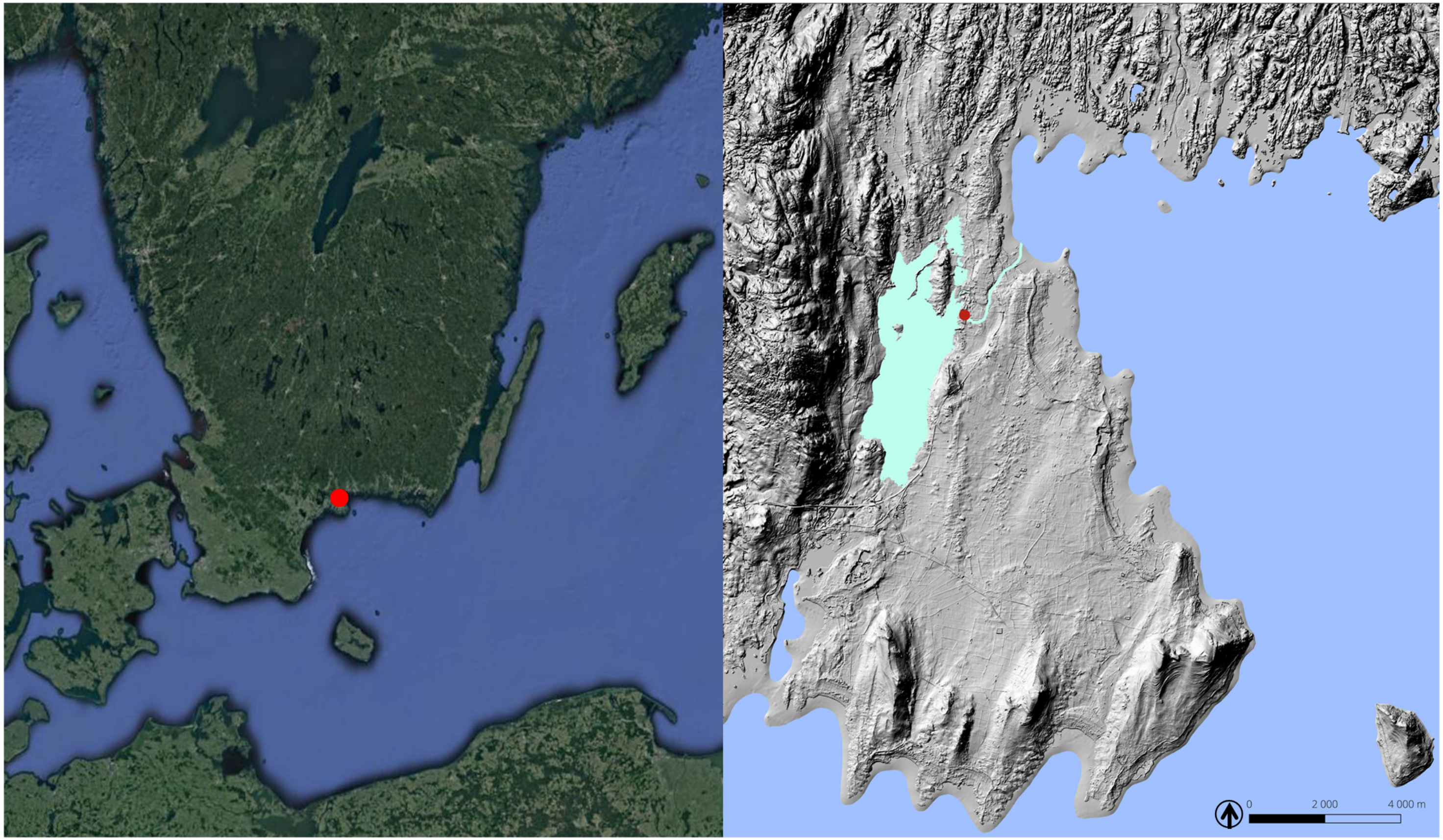

Figure 5 The location of the site Norje Sunnansund with the shoreline displacement around 9200 cal. BP (right). Picture published in papers I and II. Right map is based on a terrain model at a 5-m resolution and on LIDAR data and topographic information from the Swedish Land Survey [© Lantmäteriet i2012/892], Swedish Geological Survey (SGU) and Iowtopo2 (Seifert et al., 2001). Map by Nils-Olof Svensson, Kristianstad University. Left map from Google Earth 2016 (Data:SIO, NOAA, U.S. Navy, NGA, GEBCO).

Norje Sunnansund was excavated in 2011, under the direction of Mathilda Kjällquist (Kjällquist et al., 2016), and mainly consists of three cultural layers (Fig. 6) and one elongated pit with surrounding stake and post holes.

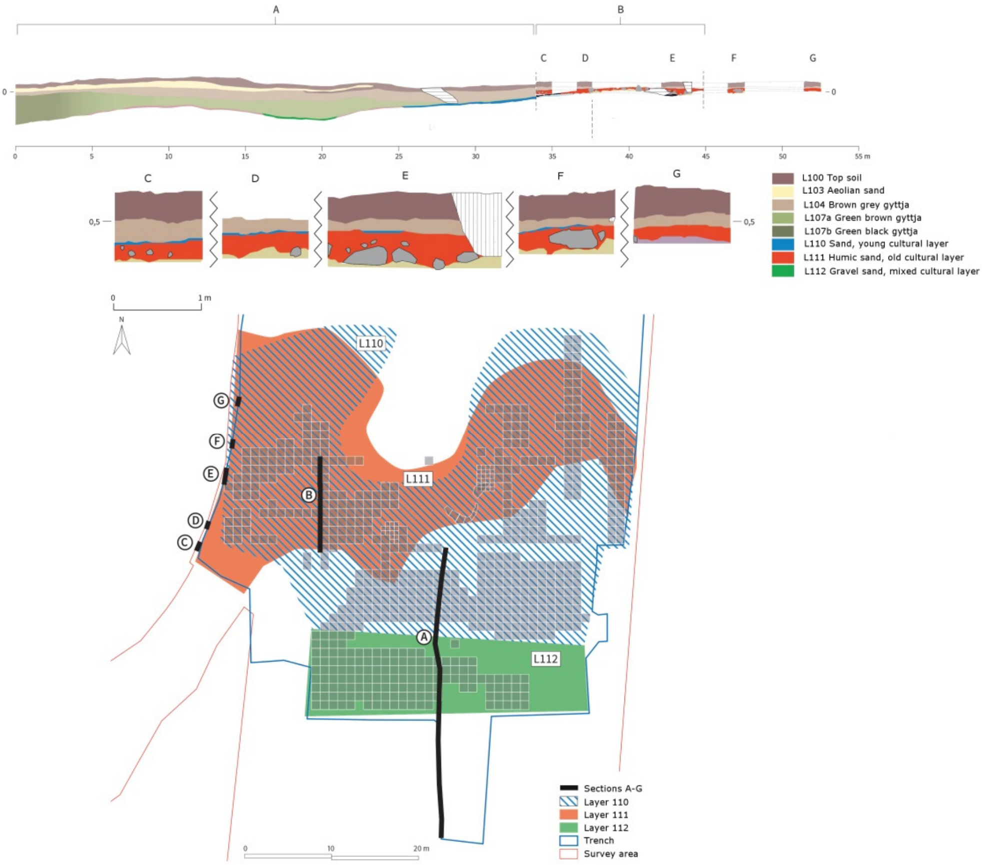

Figure 6 Plan of the sections at Norje Sunnansund and the distribution of the layers. Picture originally in Kjällquist et al. (2016), © Blekinge Museum.

The site was, at the time of occupation, located on the shores of a shallow freshwater lake (Vesan) and situated next to a stream leading out to the Baltic Sea (Fig. 5 right), which was about 2km away and also freshwater at the time (the initial Littorina stage). The settlement was surrounded by mostly hazel (*Corylus avellana*) and pine (*Pinus sylvestris*) trees, and, across the small shallow Lake Vesan, a low mountain ridge stretched for about 20 km. Therefore, the settlement would have been situated in an ecotone, i.e. in a transition environment between two biomes and, consequently, where it was possible to utilize more than one resource type.

Huseby Klev (paper IV) is located on the island of Orust, within the coastal archipelago, about 50 km north of modern-day Gothenburg, on the west coast of Sweden (Fig. 7 upper). It consists of three completely separate occupation phases. These phases are temporally placed at the transition between the Pre-Boreal and Early Boreal chronozone (PBO–EBO), radiocarbon dated to about 10300–9600 cal. BP, the Mid-Boreal chronozone (MBO), radiocarbon dated to about 9600–8700 cal. BP, and the Mid-Atlantic chronozone (MAT), radiocarbon dated to about 8000–7700 cal. BP.

Huseby Klev was excavated between 1992 and 1994 under the direction of Bengt Nordqvist, and the results were later published as a report (Nordqvist, 2005) in which Jonsson presented the original zooarchaeological analysis, where he indicated roughly what species were present on the site. The two earliest settlements were found underneath a cover of post-glacial clay, with the PBO–EBO material located in a sandy shell–clay layer and the material from the MBO located in a sandy shell layer. The MAT material was derived from a hut structure, two ditches associated with the hut, and a cultural layer surrounding these features, all filled with oyster shell remains (Nordqvist, 2005). At the time of occupation the PBO–EBO settlement was located in a narrow strait, whereas the landscape had transformed during the two later occupations and, even though the sites were in the same area, the settlements from MBO and MAT were located in a bay (Fig. 7 lower).

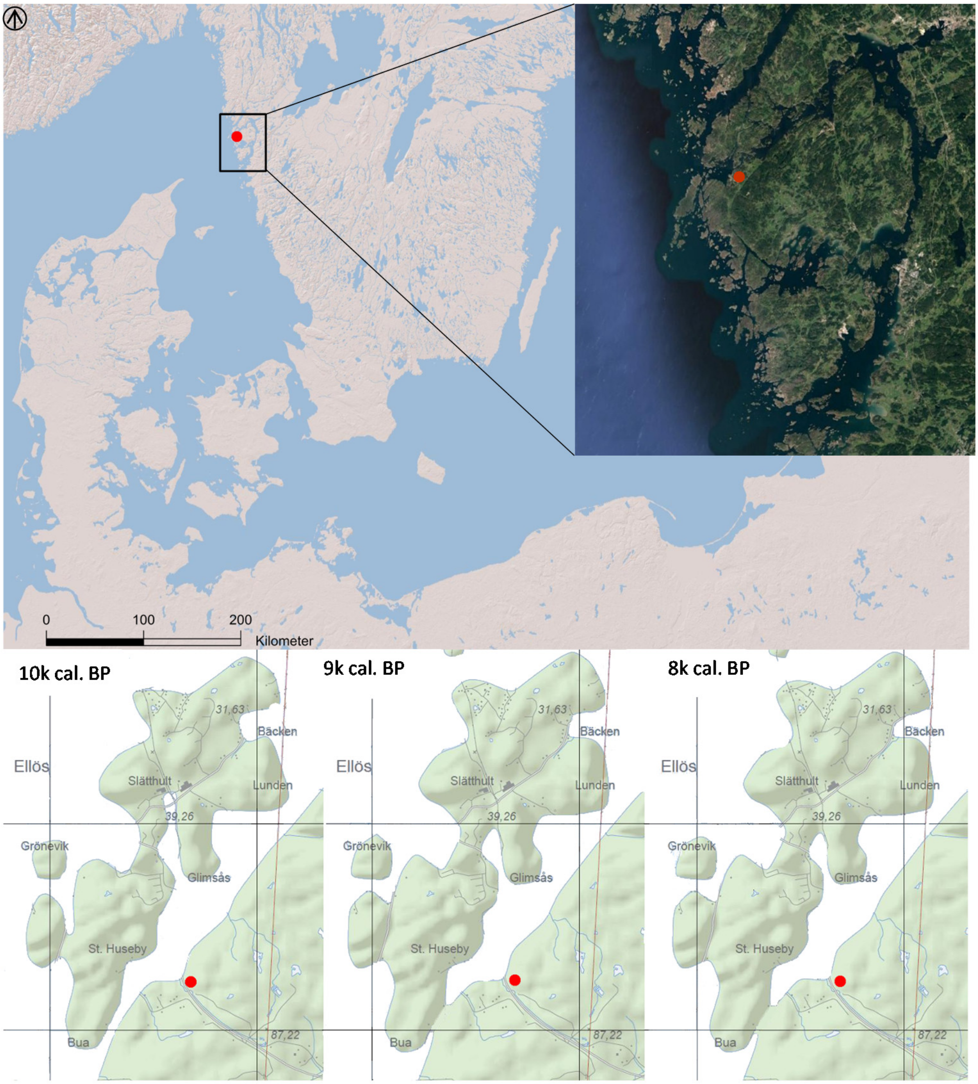

Figure 7 The location of Huseby Klev (upper) and the location of the sites at the different settlement phases (lower); left: PBO–MBO phase around 10,000 cal. BP, middle: MBO phase around 9000 cal. BP, right: MAT phase around 8000 cal. BP. Shoreline displacement based on information from SGU. Top right from Google 2017, ©TerraMetrics.

The third main study area is the island of Gotland in the Baltic Sea, from which three sites have been used in paper V. They comprise Stora förvar on the small island of Stora Karlsö, to the west of main Gotland, the Stora Bjärs burial on northern Gotland, and the site of Gisslause, which is located on the north-eastern coast of Gotland and was the principal site for paper V (Fig. 8). Gisslause is dated from around 9000 to sometime before 8000 cal. BP, possibly in connection with the 8200 cal. BP cold event (Alley and Ágústsdóttir, 2005). Gisslause was originally excavated in 1929 (Munthe and Hansson, 1930) and then in 1982 (Burenhult, 1999; Seving, 1986) and 2010 (Apel and Hongslo Vala, 2013), and consisted of a main cultural layer with a couple of features that have been interpreted as hearths. The site was, at the time of occupation, located on a small esker between a shallow lake and a bay connected to the Baltic Sea (Fig. 8 upper right).

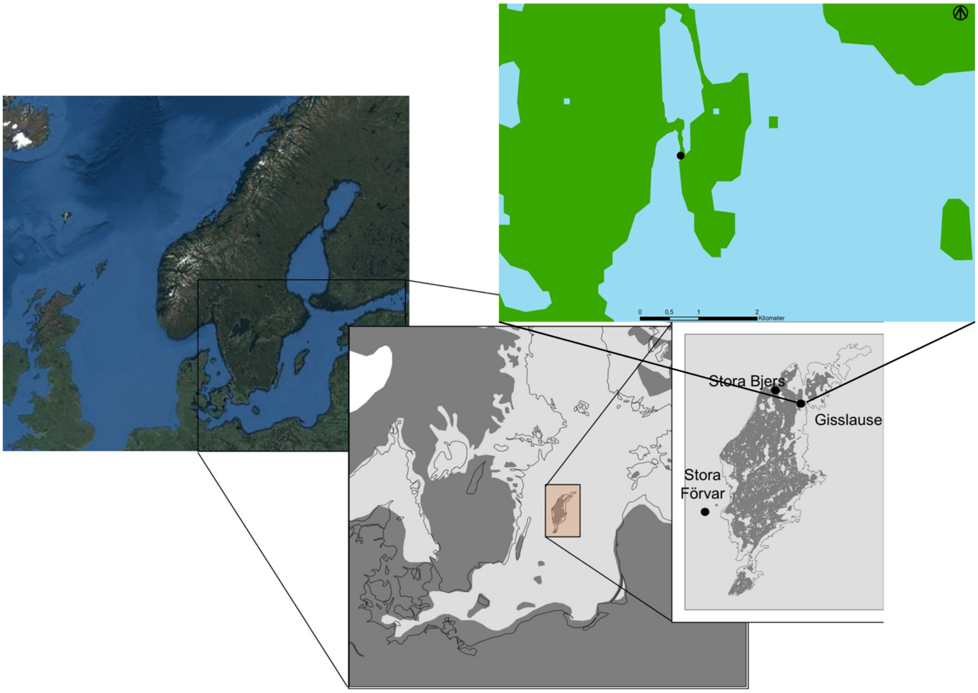

Figure 8 Map of Gotland, zoomed in on Gisslause, with the shoreline displacement shown around the time of occupation. Left map from Google Earth 2016 (Data:SIO, NOAA, U.S. Navy, NGA, GEBCO). Figure originally in paper V.

5.2. The archaeological data

The zooarchaeological remains from southern Scandinavia provided the main source of data for this thesis. However, in order to interpret the archaeological record comprehensively other disciplines were integrated into the study (Table 1). Even though five of the six articles included are presented as case studies, their results have been integrated to obtain a wider perspective, which has enabled generalizations to be made about Early and Middle Mesolithic subsistence strategies and their implications.

Table 1 Basic information about the six papers included in the thesis.

	Paper I	Paper II	Paper III	Paper IV	Paper V	Paper VI
Main investigation site	Norje Sunnansund	Norje Sunnansund	Norje Sunnansund	Huseby Klev	Gotland, Gisslause	All available sites
Location	Swedish south-east coast	Swedish south-east coast	Swedish south-east coast	Swedish west coast	Gotland in the Baltic Sea	Southern Scandinavia
Research question addressed	Storing and fermentation practice	Residential mobility	Taphonomy, mass of caught fish	Marine subsistence strategies	Reservoir effect and taphonomy	Diet (protein)
Disciplines involved	Zooarchaeology, Archaeology, Ethnography, Quaternary geology, Statistics	Zooarchaeology, Archaeology, Ecology, Quaternary geology, Ethnography	Zooarchaeology, Archaeology	Zooarchaeology, Archaeology, Ecology, Quaternary geology	Zooarchaeology, Archaeology, Physics (radiocarbon dating)	Zooarchaeology, Archaeology, Ethnography, Chemistry, Statistics
Main investigation material	Fish bones	Bones	Fish bones	Bones	Bones, ^{14}C-dating	Stable isotopes
Time period	Early Mesolithic	Early Mesolithic	Early Mesolithic	Early-Middle Mesolithic	Early Mesolithic	Early-Middle Mesolithic
^{14}C dating (cal. BP)	9600–9000	9600–8600	9600–9000	10300–7700	9200–8000	10600–7300
Chronozone	Boreal	Boreal	Boreal	Pre-Boreal–Atlantic	Boreal–Atlantic	Pre-Boreal–Atlantic
Culture group	Maglemose	Maglemose	Maglemose	Hensbacka, Sandarna	Maglemose	Maglemose, Kongemose, Hensbacka, Sandarna
Writing order	3rd	4th	1st	2nd	5th	6th
Accepted date	Jan 2016	Feb 2017	Oct 2015	Dec 2015	May 2017	Feb 2018
Publication date	Feb 2016	March 2017	Feb 2018	Feb 2018	May 2017	March 2018
Peer review	Double blind	Double blind	Single blind	Single blind	Double blind	Double blind

In paper I, the main focus is on an elongated pit (gutter) surrounded by post holes and stake holes, which were found underneath the cultural layer in a particular area of the Norje Sunnansund site. Here fish bones were more abundant than elsewhere on the site, and these fish bones are at the centre of this study: 13,302 fish bones, from the pit and the surrounding post and stake holes, were analysed and 10,137 of them could be determined to species or family level. In addition to the fish bones, four bird and 22 mammal bones were determined from these features. These bones were used, with the application of different types of analytical techniques, field observations and ethnographic analogies, to interpret the original use of the structure.

In the second paper about Norje Sunnansund (paper II), the entire zooarchaeological assemblage from the site is used, including determinations that have been presented elsewhere but with a different agenda (Boethius, 2016a; Paper I; Paper III; Boethius and Magnell, 2010), to investigate residential mobility and the level of settlement permanence. All the mammal and bird bones found at the excavation were analysed, but only about 13% of the recovered fish bones. When combining all the phases and layers, this resulted in (NISP) 1940 mammal bones, 106 bird bones and 16,180 fish bones, which were identified to species level or, where this was not possible, to family level. By using the zooarchaeological record in combination with data from ethnographic foraging societies, parallels between recent foragers and the people that once inhabited Norje Sunnansund are discussed. Furthermore, the spatial distribution of rodents (cricetids and murinids), species-dependent selective hunting strategies and seasonality indicators, from a zooarchaeological perspective, is studied.

The third and final paper about Norje Sunnansund (paper III) is on different aspects on taphonomic loss, highlighting the difficulties in quantifying archaeological fish bones and estimating original abundance. The material used in this study came from the oldest phase of the settlement, including the fermentation pit (but not the surrounding post and stake holes). The fish bones from the fermentation pit were exhaustively analysed, but only half of the feature was used (the half sieved with a 2.5mm mesh). From the oldest cultural layer around 6% of the fish bones were analysed and used in the study. Therefore, paper III is based on 15,026 species-determined fish bones from a minimum of 414 individuals, which were used to deliver different scenarios for the rough estimates of the original mass of caught fish and their implications for population size and period of occupation.

In paper IV the focus is on one of the more famous Scandinavian Early Mesolithic sites, albeit still largely unpublished: Huseby Klev. Access to the bone assemblage from the site was gained early in this PhD project, and four students (Victor Christiansson, Felicia Hellgren, Martin Nemecek and Gabriel Widmark) analysed and quantified the bone material as part of their bachelor theses, under the supervision of the author[25]. This resulted in 694 mammal, 142 bird and 1337 fish bones that were identified to species or family level. These numbers originated from the analysis of around 5% of the fish bones from the two youngest phases and 66% of the fish bones from the oldest phase, only the largest and most complete bird bones and all of the mammal bones[26]. By using the data from the different osteological analyses and by putting them in context together with archaeological assemblages from other contemporaneous sites, the site is interpreted and the results extrapolated and used as a heuristic tool to discuss general Mesolithic subsistence trends.

Paper V is a joint paper written in collaboration with three colleagues, Jan Apel, Jan Storå and Cecilie Hongslo Vala, regarding an alternative approach to studying the dietary importance of freshwater fish. The paper is based on two different types of data sets, the zooarchaeological material from a small excavation at the Early Mesolithic site of Gisslause on Gotland, and the radiocarbon dates from three Early Mesolithic Gotlandic sites. The zooarchaeological analysis generated 821 mammal, 594 fish and 47 bird bones that were identified to species or family level. The presence of freshwater fish in the zooarchaeological assemblage led to the proposition that freshwater fish bones are under-represented on all Mesolithic sites on Gotland. This proposition was then studied using the analysis of 63 radiocarbon dates from Stora Förvar, Stora Bjärs and Gisslause, and the freshwater reservoir effect stemming from freshwater fish consumption was examined.

The first five papers are more or less based on zooarchaeological analysis. The sixth and final paper differs by using the results of the zooarchaeological analyses of Norje Sunnansund, Huseby Klev and Gisslause as a framework for an isotopic study. Stable isotope data from Early and Middle Mesolithic individuals from southern Scandinavia are evaluated to address the dietary trends in different types of environments, and the zooarchaeological data from the above-mentioned sites are used to focus in on the selected sites and contextualize the human stable isotope values.

Paper VI is a joint paper (written in collaboration with Torbjörn Ahlström) based on stable isotope data ($\delta^{13}C$ and $\delta^{15}N$). For this study, 419 bones from Mesolithic Scandinavian archaeological contexts were collected and sent for stable isotope analysis. Of the 419 samples, a total of 186 isotope samples were selected for use in the study. The remaining results were discarded because of suspected

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[25] Some of the bones had previously been determined by Jonsson (although not quantified in his original report (2005)), which facilitated the analysis process.

[26] The analyses of the fish and bird bones mainly comprised the determinations made by Jonsson, but a larger part of the mammal bones were previously unanalysed. The uneven percentage of analysed fish bones from the different phases is a result of the selection made by Jonsson upon initial analysis and the much larger fish bone assemblages from the two later phases.

contamination, i.e. because the C:N atomic ratio indicated contamination (DeNiro, 1985), or were not used because they belonged to sources that were not incorporated into the dietary analysis, e.g. dogs. An additional 192 isotope values were utilized from previously analysed Mesolithic samples (Borrman et al., 1995; Eriksson, 2003; Eriksson et al., 2016; Fischer et al., 2007; Fornander, 2011; Lidén, 1996; Robson et al., 2012; Robson et al., 2016; Sjögren and Ahlström, 2016; Sten et al., 2000). Of the 378 usable bone samples from Scandinavian Mesolithic sites (Fig. 9), 82 samples were from humans. The other 296 samples were from 11 categories of animals, one mushroom and three selected plant groups. The plant groups were represented by 27 individual isotope samples extracted from modern plants in Białowieża, a primeval forest in eastern Poland (Selva et al., 2012). Plants and mushrooms from the Białowieża forest were chosen because much plant material, similar to flesh from animals, does not survive in archaeological contexts and, even if seeds and nut shells from a few plant species do sometimes survive, the difference between the edible plant material isotopic values is much less studied compared with animal bones. Plants from Białowieża were also used in the study because it is the closest and largest available forest that is restricted to modern-day access and thus is devoid of the effects of soil fertilizers and much of modern industry pollution. The Białowieża forest represents an as unaffected environment as possible, and thus the isotope baselines from plants and mushrooms from Białowieża provided the best available comparative environment and could be used as a proxy baseline for plants and mushrooms during the Early Holocene in Scandinavia. The combination of collagen isotope values from bones from Early Holocene prey animals and modern plant material was used to form isotopic baselines from which the Early Holocene human isotope values were modelled to estimate their protein diet.

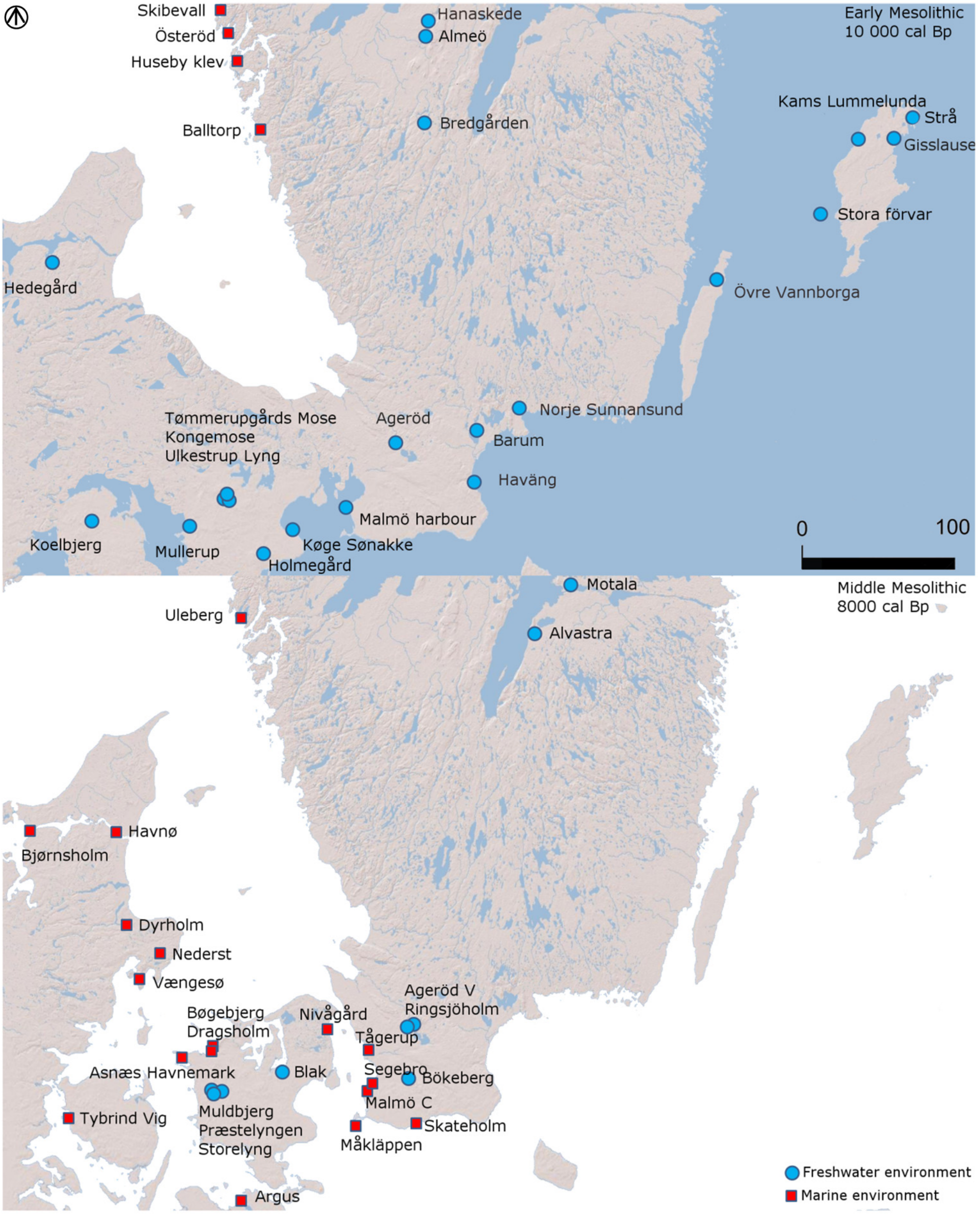

Figure 9 Map of all the Mesolithic sites with available stable isotope data used in paper VI, the Early Mesolithic sites with an approximate shoreline displacement around 10,000 cal. BP (upper), and the Middle and Late Mesolithic sites with an approximate shoreline displacement around 8000 cal. BP (lower). Map originally in paper VI. Archaeological sites added to original map by Anders Edring. The shoreline displacements were created by using information from SGU and Påsse & Andersson's calculations (2005).

6. Methods

In this thesis, many different methods have been implemented in order to investigate life in the Mesolithic. While zooarchaeological research is often considered to be closely related to the natural sciences, it is also a humanity subject. As such it is not only the quantitative results that should be a focus, but also the qualitative, i.e. how the results are interpreted[27]. IBE models have often been applied in this thesis (cf. Theoretical perspectives, Chapter 4), but it is still difficult to pinpoint exactly *how* the interpretations have been made. This is primarily because of the eclectic approach used, whereby the archaeological data have been fitted into ethnographic, environmental, biological, quaternary geological, ecological and sociological frameworks in order to facilitate interpretation. This has primarily been done in connection with fundamental human concepts, i.e. when discussing subsistence strategies, diet, health, seasonal occupation, environment, mobility and climate. These primary deductions, which stem more or less from the zooarchaeological record, have in turn been used as an abductive ‘stepping stone’ to discuss growing residential permanence and developing territoriality.

6.1. Zooarchaeological analysis

6.1.1. Identification

The core of all the papers lies in zooarchaeological methodology. The analysis and determination of species presented in the papers have used the reference collections at the Department of Archaeology and Ancient History, Lund University, Sweden, the collection at the Biological Museum, Lund University, the Zoological Museum, Copenhagen University, Denmark, the collection at the Archaeologists (formerly Riksantikvarieämbetet UV-syd) at the National Historical Museums in Sweden, and the comparative collection at the Osteoarchaeological Research Laboratory, Stockholm University, Sweden. In addition, the fish bone determinations have been facilitated by the use of fish bone compendia (Busekist, 2004; Lepiksaar, 1994; Radu, 2005). All mammal and bird bones from Norje Sunnansund and Huseby Klev have been studied, while the

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[27] Which, of course, is also true for purely natural sciences, depending on the situation.

recovered fish bone material from these sites has only been partly analysed. All recovered bones from Gisslause have been studied.

As is normal, it has only been possible to determine parts of the studied bone material from the different sites, and in general a restrictive approach was taken, i.e. if there were any doubts about the identification of a bone fragment it was recorded as undetermined. Even though the ambition level was high, some fragments that could potentially be determined, i.e. they displayed fully determinable traits, still remained undetermined. This is also normal when dealing with large bone assemblages and can arise when a species is missing from the reference collection because it is an 'exotic' species and correspondingly the zooarchaeologist cannot make the connection, because the bone has been deformed and thus does not retain its normal shape, or simply because the zooarchaeologist fails to recognize the bone fragment. The bone determinations were done by the author and, in the case of paper IV, by Christiansson, Hellgren, Nemecek and Widmark, and in paper V, by the author together with Storå and Hongslo Vala.

6.1.2. Quantification

After the initial analysis, the bone assemblages were quantified. As a standard, the number of specimens (NSP) was registered for each site, while the number of identified specimens (NISP) was used to quantify and interpret the bone materials. NISP is also the most common method used to quantify bone assemblages, and other methods of quantification are more or less associated with it (Lyman, 2008)[28]. When the zooarchaeological record was compared with other materials, NISP was the unit applied. However, other methods of quantification were also used in order to answer more particular questions. In paper III the quantification unit number of identified taxa (Ntaxa) was used to illustrate the species diversity. Furthermore, and more central to the paper, minimum number of individuals (MNI) was used as a tool to calculate the amount of meat gained from each fish species and to estimate different scenarios for the taphonomic loss of fish bones at Norje Sunnansund. MNI was derived by calculating the number of overlapping body parts from the same side of a bone element and without attempting to separate individuals further based on size or age, etc. In paper III, MNI was used, in combination with average size estimations, to model different approximated

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[28] It should also be acknowledged that while NISP is the most common method used, there are problems with it. A high degree of fragmentation in bone from one species can, e.g., lead to a falsely perceived increase in importance, and the finds of a complete carcass from one animal can (depending on how NISP is calculated) lead to a large number of identified bone fragments, even though they all come from the same animal. For further discussions of both NISP and other means of zooarchaeological quantifications see e.g. Grayson (1984), Lyman (2008) and Ringrose (1993).

scenarios of the original amount of caught fish and the implications for demography and period of use of the settlement. MNI was also used in paper I in a correspondence analysis, to compare fish NISP and MNI per litre of sieved soil with the size and volume of stake holes and post holes surrounding the fermentation pit at Norje Sunnansund.

In paper IV, problems with only using NISP as a source of comparison are exemplified with the fish bone analysis, and the estimated number of identifiable specimens[29] (ENISP) is used to highlight the difficulties involved with comparing different fish bone assemblages. In this case the arbitrary and self-defined unit ENISP was used to illustrate how skewed fish bone assemblages can be as the result of incomplete analysis (Fig. 10). ENISP was then used to illustrate and compare the fish bone abundancies from Huseby Klev and Norje Sunnansund with contemporaneous sites, where NISP had been recorded but other essential information was missing, such as the total number of specimens (NSP), number of unidentified specimens (NUSP), total weight of fish bones, identification rate or analysis frequency (% analysed fish from the total fish bone assemblage). The value of using ENISP in this case lies in illustrating the large taphonomic losses involved in fish bone archaeology and the problems encountered when analysing large fish bone assemblages because of the extensive time (and therefore costs) involved in this type of undertaking. ENISP therefore functions as a means of comparing different types of materials and can ultimately be used as a way to discuss and illustrate how the difference in quantity between different sites is also dependent on how the excavation was conducted, what methods were used for recovering fish bones, and how the post-excavation analyses were carried out and reported. Even though there are problems with comparing NISP with ENISP[30], it is still useful to illustrate a non-comprehensively analysed assemblage, such as Norje Sunnansund or Huseby Klev, where the large quantity of fish bone complicates a thorough analysis, and compare it with other type of bone assemblages. The use of ENISP allows the incorporation of large quantities of recovered but unanalysed materials (which would otherwise remain invisible in a NISP comparison) and functions as an illustrative tool, but it should not be viewed as an exact measurement.

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[29] In paper IV ENISP is referred to as both the estimated number of identified fragments and the estimated number of determinable fish bones, in an attempt to clarify its use as the number of specimens that could be identified if the entire recovered fish bone assemblage was analysed.

[30] Because the mixing of different units can be confusing, if used in ways not intended as here (other than purely illustrative), and because ENISP is an arbitrary unit while NISP is exact.

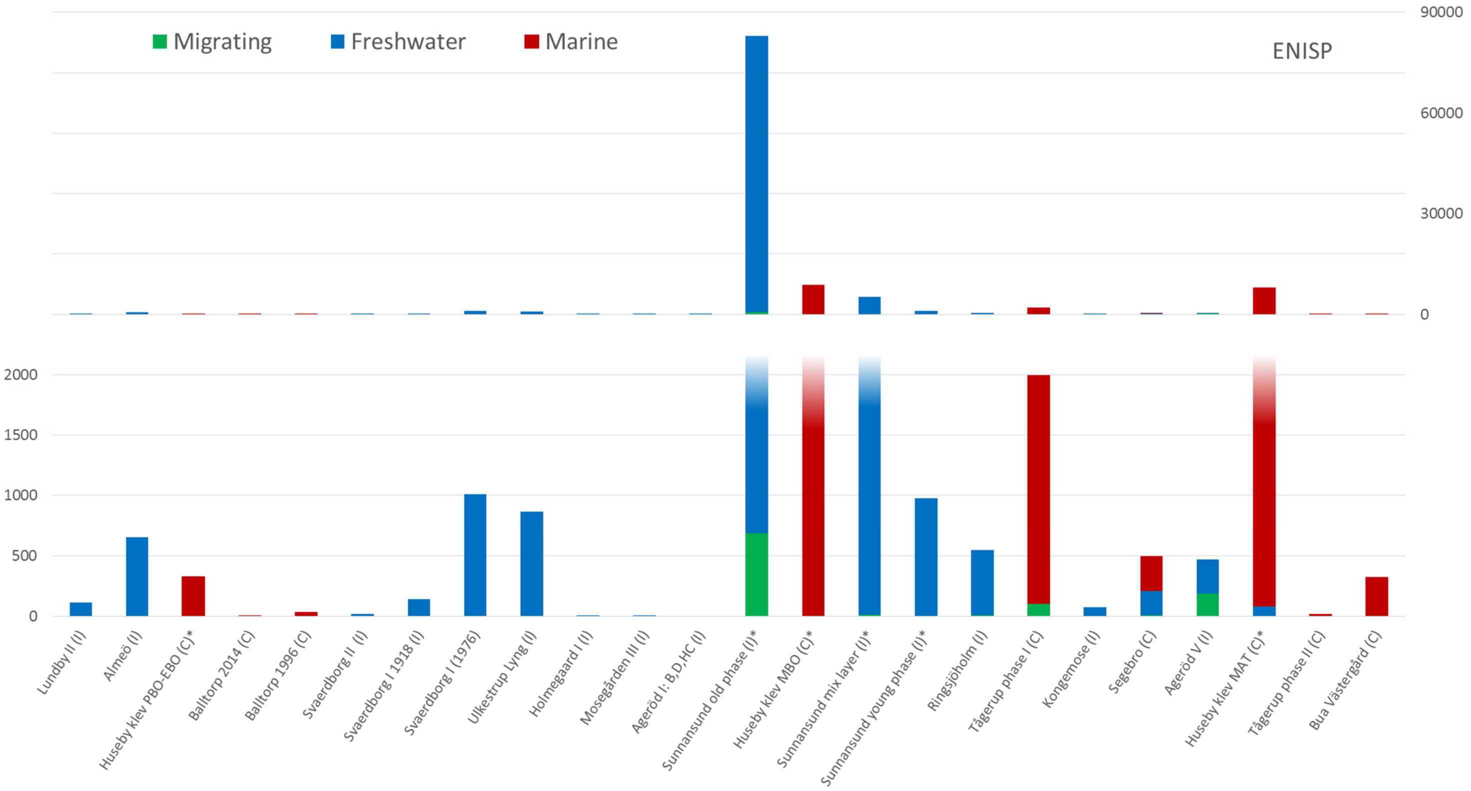

Figure 10 Number of identified fish bones from migrating, freshwater and marine fish. *Estimated number of identified fragments, if the entire recovered fish bone material had been analysed. The top part shows unaltered ENISP; the bottom part show the same data at a higher resolution to show the number of fish bones without the outliers of Norje Sunnansund and Huseby Klev. Sites displayed in chronological order. C indicates coastal environment. I indicates inland environment. Modified figure from the original, which is presented in paper IV. Figure 10 should be used as an illustrative tool when discussing taphonomic issues and not as presenting actual numbers (see paper IV).

In paper VI the zooarchaeological quantifications used in creating the prior (cf. Statistics, Chapter 6.3.2), when running the Bayesian mixing model, are based on NISP; however, the end results are presented as boxplots showing the modelled percentage of each food source represented in human protein consumption.

6.1.3. Osteometrics and regression formulas

In paper III the average size and weight of each fish species was used to present different scenarios estimating the original mass of caught fish. These data were in turn calculated from regression formulas based on individual bone measurements, which were taken according to Morales and Rosenlund (1979). The regression formulas used in the study were based on different bones for different fish species (Table 2). In cyprinids, the regression formulas were based on those for sizing roach (*Rutilus rutilus*), because the vast majority of the bones determinable as cyprinids belonged to roach. The weights of the less frequently occurring fish species were based on comparisons with bones from fish in the comparative collections, where the weight and size of the individual fish were known.

While doing this type of calculation it is important to remember that the end results have a built-in error, i.e. each step in the calculations increases the error. Therefore the derived calculation presented in paper III should not be considered a 'true' weight derivation[31], but should rather be regarded as a working tool for generating estimations to facilitate the interpretation of the material.

In papers II and V, seal measurements were also used in the analysis in order to age the seals and to gain additional seasonality data. These measurements were taken according to Ericson and Storå (1999) and compared with metric data from extant seal populations according to Storå (2001).

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[31] In other words, the estimated weight derivations are calculated from three different taphonomic loss-rate scenarios, which render three very different end results. However, the difficulties involved in estimating taphonomic loss rates and the properties of taphonomy, which imply that no standard loss rate can be applied because of unaccountable variations even within a single assemblage, make it futile to pursue a true derivation. The real value in applying this type of calculations lies in the ability to show that taphonomic losses have affected the bone material extensively, even on exceptionally well-preserved and well-excavated sites. Furthermore, it serves to put actual numbers on the original depositions, however faulty and lacking they might be, which can then be used as a working tool to anchor thoughts and discussions around, i.e. to avoid vague non-committal statements regarding fish consumption (such as they probably ate a lot of fish).

Table 2 The size and weight equations used for the different fish species. X measurements are illustrated in Morales and Rosenlund (1979) and/or in the references sited for each species.

Species	Element	Size equation	X	Weight equation	Reference
Pike (*Esox lucius*)	Dentale	$TL=119.3059*x^{0.9048}$	Anterior height of dentale	$W=10^{((3.059* \log TL)-5.369)}$	Enghoff (1994), Willis (1989)
	Parasphenoidale	$TL=181.6086*x^{0.8921}$	Smallest medio-lateral middle breadth on the parasphenoidale		
Roach (*Rutilus rutilus*)	Vertebrae 1	$TL=76.4364*x^{0.8331}$	Largest width of the posterior articulation of vertebrae 1	$W=0.0053L^{3.35}$	Enghoff, (1987), Koutrakis and Tsikliras (2003)
Perch (*Perca fluviatilis*)	Dentale	$TL=95.6287*x^{0.8530}$	Anterior height measurement of dentale	$W=0.0229L^{2.83}$	Enghoff (1994), Kleanthidis et al. (1999), Neophytou (1993)
Eel (*Anguila anguila*)	Cleithrum	$TL=278.6*x^{0.7875}$	Anterior-posterior height of the midshaft	$W=0.0003TL^{3.47}$	Thieren et al. (2012), Koutrakis and Tsikliras (2003)
	Precau. vert type 3	$TL=139.46*x^{0.9478}$	Corpus length of precaudal vertebrae		
	Precau. vert type 4	$TL=134.2*x^{0.9404}$			
	Precau. vert type 5	$TL=122.94*x^{0.9616}$			
	Precau. vert type 6	$TL=120.71*x^{0.975}$			
Whitefish (*Coregonus*), Burbot (*Lota lota*), Smelt (*Osmerus eperlanus*), Ruffe (*Gymnocephalus cernua*), Zander (*Sander lucioperca*), Salmonid (Salmonidae), Trout (*Salmo trutta*)			Comparative size		

6.1.4. Age estimations

Skeletal age estimations were carried out in order to understand hunting strategies, exploitation patterns, seasonality and mobility. In general, the method first presented by O'Connor (1982) has been used, where the post-cranial epiphyseal stages are divided into different categories based on the timing of varying epiphyses fusing with the shaft of the bone. In order to obtain as many age-determinable fragments as possible and because of a presumed added taphonomic loss of juvenile bones, because they are more fragile and structurally weaker than bones from adult animals, intact or almost intact bones that could safely be determined as deriving from very young individuals, based on size and bone texture, were systematically classified as belonging to the youngest age category of the different species.

In general, a low abundance of teeth in the bone assemblages made their use difficult, as the sample size would have been too small to provide good information. Consequently, teeth were not used to study age structures (apart from roe deer in paper IV).

In paper II, mammal age estimations were carried out using post-cranial epiphyseal fusion and osteometrics. Epiphyseal fusion was used for wild boar according to Zeder et al. (2015), for roe deer according to Tome and Vinge (2003) and for red deer, because no comprehensive study exists, according to Bosold (1968) for phalanges and metapodials, Lyman (1991) for humerus, femur, radius and tibia, and Heinrich (1991) for the remaining skeletal elements. Seal age estimations were based on both epiphyseal fusion and on osteometric comparisons with extant seals according to Storå (2001). The same aging references and methods were applied in papers IV and V, with the difference that only seals were available on Gisslause and in paper IV Bull and Payne (1982) was used to study epiphyseal fusion for wild boar, as Zeder et al. (2015) was unpublished at the time of writing that paper. Furthermore, in paper IV white-beaked dolphin and porpoise age determinations were based on epiphyseal growth studies of common bottlenose dolphins according to Costa and Simões-Lopes (2012), and roe deer age assessments were based on tooth wear according to Habermehl (1961) and by comparison with mandible sequences of extant roe deer with known age of death from the Copenhagen Zoological Museum.

6.1.5. Sex determination

There are many benefits to studying sex distributions, such as investigating game selection, hunting patterns, ecological modelling, raw material needs, etc., when assessing hunting strategies. However, because of the relatively large fragmentation rates and few available sex-determinable bone fragments in the assemblages, it was of limited use in this research. When possible, sex determinations were based on the morphological criteria for pelvises as defined by Lemppenau (1964) for cervid species and Mayer and Brisbin (1988) for wild boar canines, and osteometrics were used for species with pronounced sexual dimorphism. However, because of the limited number of fragments where any of these criteria could be applied, sex determinations have only been noted and sex distributions have not been quantified or further interpreted. For specific information regarding the available sex distribution on Norje Sunnansund see Kjällquist et al. (2016).

6.2. Stable isotopes

Stable isotopes from nitrogen ($\delta^{15}N$) and carbon ($\delta^{13}C$) have been used in diet studies for around 40 years (DeNiro and Epstein, 1976; 1978; 1981; Schoeninger and DeNiro, 1984). By studying the different ratios of two non-radioactive isotopes of an element it is possible to investigate the conditions that led to the formation of the sample in question. The use of stable isotopes in dietary studies is possible because the levels of $\delta^{15}N$ and $\delta^{13}C$ in an organism depend on what the organism has eaten, as they are a derivation of the corresponding values in the diet[32], with a slight increase along the trophic ladder through isotopic fractionation as a result of differential digestion or fractionation during assimilation and metabolic processes (McCutchan et al., 2003), i.e. the fractionation rate. Both nitrogen and carbon are present in all organic tissues of an organism[33] and thus are also preserved in bone material, and consequently can be used in archaeological palaeodietary studies. The use of stable isotopes is based on the principle that $\delta^{15}N$ and $\delta^{13}C$ values vary among different species and the fractionation rate between plants, prey animals and predators is ‘known’[34], thus, in theory, enabling a comparison of the isotope values from human collagen with baselines from prey animals and plants. However, problems have recently started to emerge when a large input of freshwater fish is suspected in the diet (Hedges and Reynard, 2007), as the method differentiates best between a marine and a terrestrial diet (Tauber, 1981). For example, freshwater fish display similar $\delta^{13}C$ values to terrestrial animal species, although with a much wider range because of the unique chemical composition of different freshwater systems, often depending on the trophic state

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[32] Which in turn have values deriving from their diet and living environment.

[33] Although studies have shown variations in $\delta^{15}N$ and $\delta^{13}C$ values depending on the tissue being investigated (Dalerum and Angerbjörn, 2005).

[34] Lately the fraction rate has been shown to vary a lot more than originally suspected; this is described in detail below and throughout paper VI.

of the lake and δ^{13}C variations in the phytoplankton (Grey et al., 2000), with corresponding variations in the fish eating the phyoplankton. δ^{15}N values have also been used to separate marine from terrestrial sources, because δ^{15}N is enriched with each consumer–predator step in a food chain, i.e. marine animals have elevated δ^{15}N values because a marine food chain is longer than a terrestrial chain; consequently a marine human diet is detectable through elevated δ^{15}N values. However, a marine food chain is longer than a freshwater food chain (Cohen, 1994). Furthermore, even though the food chains are generally longer in aquatic freshwater systems compared with terrestrial systems, some freshwater fish species, such as cyprinids, live on a low trophic diet (Wheeler and Jones, 1989:30), consuming mostly small invertebrates, plankton, algae and plant debris. As a result, cyprinids display similar or only slightly elevated δ^{15}N values that clearly overlap with values from terrestrial omnivores and herbivores (cf. Schmölcke et al., 2016). This makes a diet based on cyprinids difficult to distinguish from one based on terrestrial mammals by means of stable isotope analysis. As the Baltic Sea was freshwater during the Early Mesolithic period, and because of the general lack of marine sites, most of the humans present from the Early Mesolithic period lived in a freshwater environment. As a result they would only have been in contact with freshwater-living fish and seals, thus complicating human stable isotope interpretations based on low levels of δ^{15}N elevation as the values could derive from a protein diet based on plants, cyprinids or terrestrial ungulates.

In order to use stable isotope data from freshwater environments, with a suspected protein input from freshwater animals, paper VI uses human stable isotope data together with zooarchaeological data in the analysis of the material (see Bayesian diet mixing modelling, Chapter 6.3.2). In this study the stable isotopes δ^{13}C and δ^{15}N in bulk collagen were investigated in order to estimate the relative human dietary sources. In terms of collagen derived from the skeleton, this reflects the average diet of an adult individual's approximately last 10 years of life, assuming a bone remodelling rate of around 5–10% per year dependent on the age and activities of the individual and on the bone element examined (Kini and Nandeesh, 2012; Sims and Martin, 2014). On five occasions the only human stable isotope values available were from teeth (cf. paper VI and fig. 24), in which case it was not the adult diet being represented but the diet of the individual as the tooth was forming, i.e. during childhood or adolescence, depending on the tooth sampled.

To investigate the protein diet of Early and Middle Mesolithic Scandinavian foragers, all known, at the time of analysis (December 2016), human isotope values were modelled in order to obtain both the 'average human protein diet' in different environments and time periods and site-specific diet estimations. The human isotope values were modelled using a baseline of 15 plausible protein sources, following the principle, 'you are what you eat (plus a few‰)*'* (DeNiro and Epstein, 1976). The sources used in the study were: northern pike, freshwater aquatic mammal, freshwater cata/anadromous fish[35], terrestrial herbivores, marine high trophic fish, cyprinids, marine low trophic fish, marine aquatic mammal, marine cata/anadromous fish, freshwater mid-trophic fish, terrestrial omnivores, berries, fruits, hazelnuts and mushrooms (for diet source species details see paper VI).

When working with human stable isotope signals, the sources are not the only important information needed to derive a human diet. The fractionation rates ($\Delta^{13}C$ and $\Delta^{15}N$), i.e. the rates at which carbon and nitrogen isotopes increase between consumer and diet in the food chain, vary depending on environment (terrestrial, marine or freshwater), taxonomy, trophic level, metabolic rate, tissue and diet quality (Dalerum and Angerbjörn, 2005; Florin et al., 2011; McCutchan et al., 2003; Vanderklift and Ponsard, 2003). Studies in ecology have stressed the importance of applying the correct fractionation rate when studying stable isotopes and have shown large variation given different premises (Caut et al., 2008; 2009; Hussey et al., 2014). Therefore, a theoretical[36] standard deviation to set fractionation factors between diet (the collagen from contemporaneous animal sources and material from modern plants and mushrooms) and human collagen was applied. In paper VI this was set for an average $\Delta^{13}C_{\text{plant material-human collagen}}$ at 5‰± 0.9 and $\Delta^{13}C_{\text{animal collagen-human collagen}}$ at 1‰±0.9, following general guidelines (Malainey, 2011), with an increased standard deviation to account for variation. $\Delta^{15}N$ is somewhat more complicated as large and inconsistent fractionation factor variations have been noted (Ambrose, 2000; Bocherens and Drucker, 2003; Caut et al., 2008; 2009; Hussey et al., 2014; Jenkins et al., 2001; O'Connell et al., 2012; Sponheimer et al., 2003), suggesting that the originally used $\Delta^{15}N$ of 3‰ (DeNiro and Epstein, 1981; Schoeninger and DeNiro, 1984) is incorrect. In order to account for the highly variable $\Delta^{15}N$ values, the $\Delta^{15}N$ offset was set between the most commonly used fractionation factor in ecological studies of $\Delta^{15}N$ 3.4 (Minagawa and Wada, 1984; Post, 2002) and a recent study suggesting a diet–human $\Delta^{15}N$ of 6‰ (O'Connell et al., 2012). Therefore, the fraction rate for $^{15}N_{\text{all sources}}$ was set at 4.7‰±1.3, where the standard deviation catches fractionation rates between 3.4 and 6‰ (Table 3). A wide fractionation rate span increases the plausible diet source combination, which can result in the human isotope values observed; however, this was deemed the most scientific approach because of the uncertainties connected with variations in the fractionation factors between prey and consumer.

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[35] Catadromous fish: species that live in freshwater and migrate to saltwater environments to spawn. Anadromous fish: species that live in saltwater and migrate to freshwater environments to spawn. Freshwater cata/anadromous indicates that the fish was caught in a freshwater environment. Marine cata/anadromous indicates that the fish was caught in a marine environment.

[36] Non-empirical.

Table 3 The fractionation factors applied in paper VI.

	$\Delta^{13}C$	SD ^{13}C	$\Delta^{15}N$	SD ^{15}N
Plant material - human collagen	5	0.9	4.7	1.3
Animal collagen - human collagen	1	0.9	4.7	1.3

6.2.1. Bulk collagen extraction

In order to collect a sufficient amount of material for paper VI, museums and excavating institutes in Sweden and Denmark were visited to sample Mesolithic bone material. The collagen from the sampled bones was then extracted at Cornell University, Ithaca, USA (96 samples), Copenhagen University, Copenhagen, Denmark (314 samples), Lund University, Lund, Sweden (7 samples) and Chrono Laboratory at Queen's University, Belfast, UK (2 samples).

At Cornell University, the collagen was extracted according to Ambrose (1990), after first being cleaned with pressurized gas to blow away loose contamination. After the first 96 collagen samples had been run for $\delta^{13}C$ and $\delta^{15}N$ isotopes it was clear that 71 of the 96 samples (74%) displayed a biased C:N atomic ratio ($\geq 3.7, < 2.9$), indicating contamination (DeNiro, 1985). This was considered to be a high contamination rate and a new extraction method was sought to try to minimize the level of contamination. The next 314 bone samples were extracted in the geological department at Copenhagen University and the collagen was extracted according to a modified Longin (1971) procedure as developed by Richards and Hedges (1999) and recommended by Jørkov et al. (2007). The results from Copenhagen yielded somewhat better results (uncontaminated collagen was extracted from 173 out of the 321 samples, i.e. 54%), although the proportion of contaminated samples in the first run might have been because of a larger proportion of fish bones, which are more likely than mammal bones to display collagen diagenesis or contamination.

Two of the seven samples extracted at Lund University displayed a C:N ratio within the acceptable range and the method used here was adapted from Brodie et al. (2011). The two samples extracted at Belfast were made following Brown et al. (1988), Longin (1971) and Ramsey et al. (2004). All of the extracted collagen, except the two samples from Belfast, were run at the Cornell stable isotope laboratory using combustion analysis at 1000 °C on a Carlo Erba Elemental Analyzer (Italy), connected to a Thermo Scientific Delta V Isotope Ratio Mass Spectrometer (Germany). The two samples from Belfast were measured on a Delta V Advantage EA-IRMS.

6.3. Statistics

Two types of statistical analyses were used to enable interpretation of the data set: correspondence analyses in paper I and Bayesian diet mixing modelling in paper VI.

6.3.1. Correspondence analysis

Correspondence analysis is used to reduce the dimensionality of a data set to enable visualization, i.e. to map the data in a two- or three-dimensional realm (Greenacre, 2007; Nenadic and Greenacre, 2007). A correspondence analysis works similarly to a principal component analysis: it reduces data values from multiple dimensions into an observable two/three-dimensional scatter plot, i.e. a graphical display of the association between different categorical variables based on chi-square (χ^2) statistics (Beh and Lombardo, 2014). In other words, each entry point is plotted to a coordinate map where the average value is indicated by the origin (the centre were the axes intersect). Depending on how the unique entry points cluster on the map and their distance from the average value, it is possible to study the correspondence between the investigated subjects. When studying the 'map', it is important to relate the data to the inertia of the illustration. The inertia is basically a measurement of the individual dimension's potential to explain the frequency (percentage) of the χ^2 values. In practice it means that the inertia decreases with increasing dimension number, and with archaeological data most of the χ^2 values can often be explained in the first few dimensions.

The ability of correspondence analyses to visualize the reduced dimensionality of large data sets makes it possible to interpret the correlation between categories and variables. In paper I, correspondence analysis was used to study the relation between stake and post holes surrounding the fermentation pit and to investigate fish species distribution across the settlement. In the first case the number of identified fish bones and number of identified individuals per litre of sieved soil were related to the size and volume of each stake and post hole. In the second case the settlement area was divided into six zones and related to the number of identified fish bones from each species. By using a correspondence analysis it became possible to investigate patterns in the bone assemblage that would otherwise have been difficult to detect. The correspondence analyses were done using the 'ca' package (Nenadic and Greenacre, 2007) in the computation platform R (R Core Team, 2016).

6.3.2. Bayesian diet mixing modelling

When studying stable isotopes in bulk collagen it has traditionally been difficult to interpret the data if multiple diet sources with similar isotope signals are considered (Webb et al., 2015). In order to facilitate interpretation in a traditionally multi-dietary source context, i.e. among foragers, while still investigating bulk collagen, Bayesian statistics were applied to the isotope data. Bayesian statistics is a way of disentangling the mixture of multiple sources to estimate the probability of something occurring in a certain way. When applied to human stable isotopes, as done in paper VI, it shows a posterior, i.e. 'likelihood' quantification, for each individual dietary source contribution to the overall protein diet during the formation of the sampled bone in question. In order to obtain this posterior, Bayesian diet mixing models generate data for each possible combination of dietary sources, which combined sum up the diet of the individual or group of individuals being investigated. This was done using SIAR, Stable Isotope Analysis in R (Parnell et al., 2010), which is a package in the computation platform R (R Core Team, 2016). When SIAR was created, Parnell et al. (2010) introduced an algorithm to estimate proportions of sources in a consumer's diet based on Bayesian analysis. When using SIAR, a baseline of different plausible sources is created, to which fractionation rates and standard deviations between consumer and prey are added. This is done to generate plausible diet scenarios, whereby means and variances are accepted as input. Based on a linear model, Bayesian mixing estimates the proportion of sources using a Markov Chain Monte Carlo algorithm, which allows sampling from a probability distribution based on the construction of a Markov chain, i.e. a method that allows predictions to be made of the future of the process based solely on its present state (Rozanov, 1982), and is given the constraint that the proportion of sources sums to one. Bayesian models deliver probability distributions or point estimates of tractable central tendencies, i.e. in this context the model quantifies the individual dietary source contributions to the overall dietary protein. The results in paper VI are presented as separate, uniform environmentally dependent chronological period boxplots, and as informed archaeological site-specific boxplots.

Uniform mixing model: when running an SIAR uniform model, no other information is added into the program except the basic values of the subject being analysed (in the case of paper VI, Early and Middle Mesolithic humans), the sources 'responsible' for the observed $\delta^{13}C$ and $\delta^{15}N$ values in the investigated subject(s), and the fractionation rate, with standard deviation, between consumer and diet. In the uniform model all dietary sources are, prior to analysis, assumed to have been equally likely to contribute to the diet of the investigated subject. When the uniform models are run, the 30,000 most likely scenarios are generated, where each one of the posterior combinations produces the observed $\delta^{13}C$ and $\delta^{15}N$ values in the investigated subject. From these data boxplots are created. Here, the most likely scenarios (the boxes) are presented as the median of each dietary source with the upper and lower quartiles added, i.e. the middle number between the median and the maximum value (upper quartile) and the median and the minimum value (lower quartile), and with whiskers added to include the outliers, which represent the range of plausible but more unlikely dietary combination scenarios (see paper VI).

Informed mixing model: an informed diet mixing model functions similarly to a uniform model, i.e. it needs the same basic value inputs (subject, source and fractionation factor). However, where the uniform run assumes that all dietary sources are equally plausible, the informed mixing model assumes that all sources cannot be equally likely, and weighs the information based on prior information. This is done following Bayes' theorem: p(A|B) = p(B|A) p(A) / p(B), where p(A|B) (probability of A given B) is the probability of finding observation A, given that additional evidence B is present. Hence, when running an informed mixing model, additional *prior* information is added. In paper VI the zooarchaeological material from three different sites (Norje Sunnansund, Huseby Klev and Gisslause) was used and the NISP from each source category was added to a framework based on the average diet of all known and available ethnographic foragers at the latitude of southern Scandinavia (Marlowe, 2005). The added ethnographic framework was used to compare the possible dietary input from plants, fish and mammals on more equal terms, as the enhanced taphonomic losses associated with the recovery and preservation of both plant materials and fish bones would otherwise prevent this type of comparison. Furthermore, the amount of protein in different types of diets varies. Therefore, and because the ethnographic framework was constructed from whole diets (and not the protein part), corrections were made to rectify this bias and individual dietary sources were scaled according to the average protein proportion of the relevant species (see paper VI for further details).

In paper VI the isotope data are also presented in a bivariate form. However, instead of only presenting the source baselines as their mean values with added standard deviation, which is common in archaeological isotope studies, the sources are also illustrated as Standard Ellipse Areas corrected for sample size (SEAc). These were calculated based on the eigenvalues (a and b) of an eigen analysis of the covariance matrix involving the δ^{13}C and δ^{15}N values as x and y coordinates (SEA=πab). This addition was done because these values provide reliable descriptors of the community structure (Jackson et al., 2011), i.e. when illustrating the overlapping baselines from different diet sources a SEAc analysis embrace the covariance between isotopes, which cannot be illustrated in univariate representations. Similarly to the source data being fitted into a SEA illustration, the human isotope values were divided into a temporal framework (Early and Middle Mesolithic) and the respective SEAc calculated to illustrate the human isotopic niche width for the time periods in question.

7. Results

As mentioned in the Introduction (Chapter 2), the main purpose of this project was to investigate subsistence strategies and study the importance of aquatic resources during the Early and Middle Mesolithic period in southern Scandinavia, in order to advance our knowledge of those societies and deduce the implications of their subsistence strategies and selected lifestyle. This was approached from six different angles, represented by the six papers included in the thesis, each focusing on a small but important area that was considered to be in need of clarification or examination.

7.1. Paper I – Something rotten in Scandinavia

In paper I, the aim was to answer questions regarding how large-scale storage can be traced in archaeological foraging contexts, what preservation techniques were applied to larger quantities of fish, and how these findings impact our understanding of early foraging societies in northern Eurasia.

The results in paper I were mainly derived from ichthyo-archaeological analyses and archaeological evidence; however, they were also based on the use of statistics and the heuristic use of ethnographic analogies. During the excavation of Norje Sunnansund, one area of the cultural layer emerged as having even more abundant fish bone than the rest of the site. Furthermore, this area revealed large amounts of bark[37], which was not observed anywhere else during the excavation. In the cultural layer above what was later interpreted as a fermentation pit, one of the most elaborate finds from the site was found: a slotted bone point/dagger decorated as a fish skeleton (Fig. 11).

Figure 11 The slotted bone point/dagger decorated as the skeleton of a fish. Photo: Staffan Hyll, © Blekinge Museum.

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[37] Most likely from pine trees.

When the cultural layer had been removed, an elongated feature appeared in stark contrast to the surrounding clay. This pit/gutter was surrounded by a number of small stake holes and a few larger post holes (Fig. 12 right). During the excavation of this pit, highly degraded plant fibres could be noted lining the clay walls (Fig. 12 left). It was therefore apparent during the excavation that this feature was something out of the ordinary, but it was not until after the initial zooarchaeological analysis had been carried out that answers regarding its use could be sought.

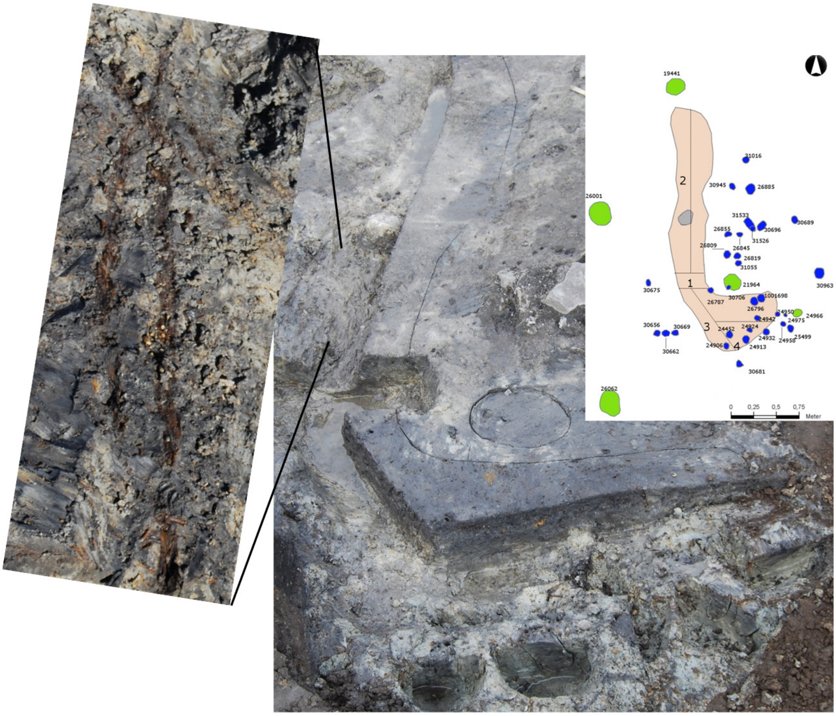

Figure 12 The fish fermentation pit from Norje Sunnansund. Middle: photo after half of the feature had been excavated, including some of the excavated stake holes. Upper right: total station documentation printout from the Intrasis project. Left: degraded plant fibres lining the clay wall. Photo: Adam Boethius, © Blekinge Museum.

Of the 10,137 identified fish bones from the feature, around 79% came from cyprinids, mainly roach, but other freshwater fish species were also present, of which perch and pike dominated, followed by eel, burbot, ruffe, whitefish, zander, smelt, arctic char (*Salvelinus alpinus*) and indeterminable salmonids in declining order of presence. In addition, many of the pike caudal vertebrae displayed collapsed vertebral bodies (Fig. 13), which indicated that they had been subjected to an acid environment.

By using a correspondence analysis, the smaller stake holes could be shown to hold large amounts of fish bones per litre of sieved soil, while the larger post holes held much lower fish bone frequencies, which indicated that the stakes had been repeatedly removed and replaced (allowing them to be backfilled with the same content as in the main pit), while the post holes had been more permanent. In addition to the large number of fish bones from the feature, 22 mammal bones were identified. These were mainly phalanges from wild boar and seal, and fragments from the inside of seal skulls. Fetus vernix (the greasy substance covering fetuses and new born mammals) had possibly been used as part of a processing ‘recipe’, based on finds of fetus bones from both roe dear and seals in the area surrounding the pit. By applying a large number of ethnographic analogies, from circumpolar groups around the world, and by discussing the chemical prerequisites for fermentation without the use of salt, it was possible to show that the only plausible explanation that could incorporate all the observations made in connection with the feature was that the people had fermented fish there in order to facilitate long-term storage.

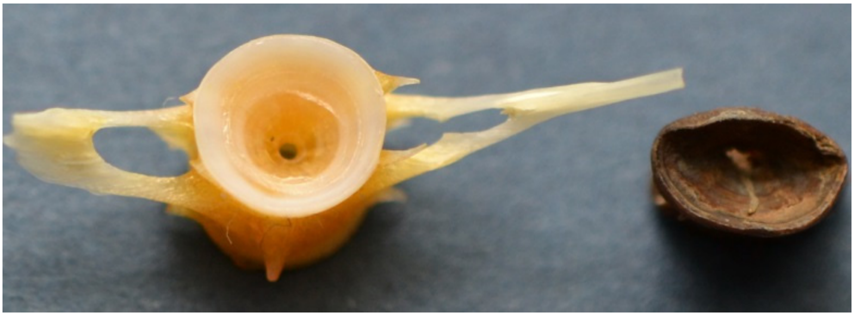

Figure 13 Pike caudal vertebrae with collapsed vertebral body from the fermentation pit at Norje Sunnansund (right) compared with a modern pike caudal vertebrae (left). Photo: Adam Boethius.

7.2. Paper II – Signals of sedentism

This paper examined the hypothesis that it is plausible for ancient foragers to have lived a less mobile life with limited residential mobility than previously assumed. This was investigated by discussing whether it is possible to identify the presumably many active strategies taken to ensure survival and by exploring whether circumstantial evidence can provide information about mobility and delayed-return subsistence strategies. The problems were tackled by considering five different lines of enquiry: seal hunting, the hunting of ungulates, fishing, opportunistic hunting (animals hunted for fur and bird hunting) and rodent intrusions. This was mainly done by applying standard zooarchaeological methods to the bone material from the site. By addressing the different lines of enquiry separately, various suggestions could be made, as follows.

Seal hunting was mainly carried out during late winter to early spring, was done from the ice, and was focused on mothers and their cubs. The target species included ringed seal (*Phoca hispida*) and grey seal (*Halichoerus grypus*), mainly for other raw materials[38] even if dietary needs were also met. The reason for highlighting raw materials is because the seal hunting would have been limited to short seasonal forays[39] and would have been carried out on a comparably small scale.

Ungulate hunting strategies differed from those of seal and also differed between the ungulate species. Elk and aurochs were rare in the assemblage, which, it is suggested, was the result of previous over-exploitation in coastal areas, as both species are much more common on contemporaneous inland sites (Eriksson and Magnell, 2001; Magnell, 2017). Furthermore, a difference in age-related kill-off patterns was detected between wild boar, roe deer and red deer. Wild boars had been hunted regardless of how old they were, with both young, middle-aged and old individuals present in the assemblage. Among roe deer, young individuals had been more sparingly hunted, while for red deer no young animals could be detected in the assemblage and the bulk of red deer had been killed between the ages of 2.5 and 4 years. These hunting patterns were interpreted as having been caused by a demand for raw materials to make clothes, tools and weapons, even though the meat they provided also contributed to a significant part of the diet. The targeting of adult red deer is suggested to be because bones from fully grown individuals are both sturdier and larger and, correspondingly, they can provide a larger return than younger individuals. In other words, to yield an equal amount of raw material (and meat) a larger number of individuals would have to be killed if younger animals were targeted. Thus, for species with low reproduction rates, this could have depleted the area around Norje Sunnansund of, e.g. red deer, and perhaps necessitated an elevated logistical mobility, as the foragers would have had to travel further and further away from the settlement to procure the desired resources. This observed pattern could, however, also be driven by ecological factors[40], such as better hunting grounds for young red deer being somewhat further away from camp compared with the hunting grounds for wild boar (cf. Discussion, Chapter 8.6.2).

Fishing was interpreted as having provided the bulk of the food, with indications of year-round exploitation[41], but with intensification during the spawning season, when fish could be extracted in large quantities and stored for later consumption. Therefore, fishing practices, together with year-round seasonality indicators (Fig.

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[38] Blubber and fur/skins.

[39] Though the raw materials could have been used all year round.

[40] In other words, taphonomic reasons stemming from species-specific differences in ecological habitat preference.

[41] As suggested by the large size variation in all but cyprinid fish species (see fig. 15).

14), provided evidence of delayed-return subsistence strategies, suggesting that a large-enough quantity of fish could be caught to sustain a sedentary population.

Both animals hunted for fur and birds were categorized as opportunistically hunted. This was because these animals were represented by rather low numbers of identified bones from each of the species. These opportunistically hunted animals were, as the name implies, hunted more sporadically upon encounter. Birds seem to have been hunted all year round, with different species of migratory birds having been present at different periods of the year; small fur-game species seem to have been hunted during the winter, while larger fur-game species seem to have been hunted both to provide furs and to remove them from the area close to the settlement.

Lastly, rodent intrusions at Norje Sunnansund were examined. By examining the spatial distribution of rodent bones, intensifications were noted in the area around the fermentation pit. This was interpreted as a further indication of the permanence of the structure and it was suggested that, even though built as a permanent installation, the fermentation pit had, on occasions, been moved because of rodent intrusion and destruction of the fermenting fish, thus suggesting the possibility of more fermentation pits at Norje Sunnansund. Overall, paper II suggested that it is possible to identify plausible ‘signals of sedentism’ and that they are traceable in the archaeological record from Norje Sunnansund.

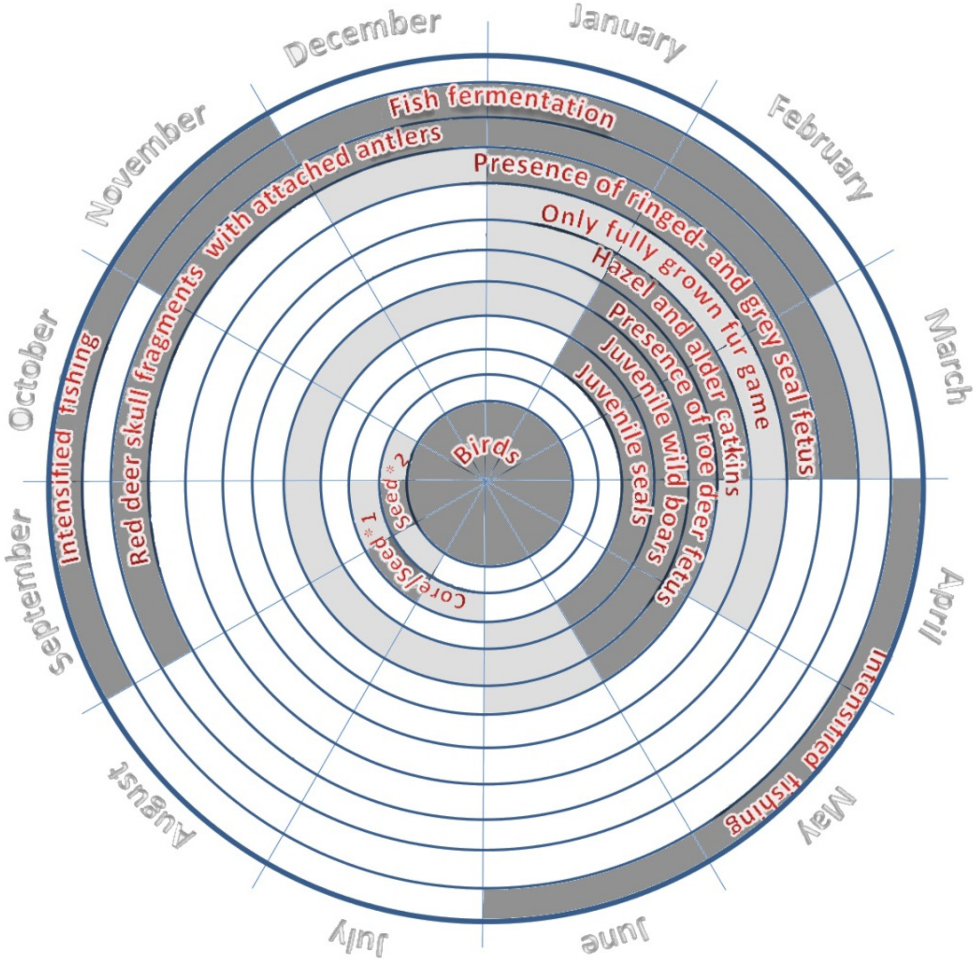

Figure 14 Seasonality indicators from Norje Sunnansund. Dark grey shows likely seasonal exploitation, light grey shows conceivable seasonal exploitation. Figure originally in paper II.

7.3. Paper III – The use of aquatic resources

Paper III addresses taphonomic biases when investigating the importance of fish. Taphonomic issues are discussed in general terms to highlight the many difficulties and challenges associated with revealing a diet based on freshwater fish consumption. In this paper, the focus is on Norje Sunnansund and a variety of sizing methods and regression formulas used to estimate the amount of caught fish excavated on this site. This paper was written to pursue the aim of understanding how Early Mesolithic societies are perceived and to illustrate how taphonomic loss affects even well-preserved sites, and that the loss rate is difficult to quantify. Following on from these objectives, the paper also aims to illustrate how many people freshwater fishing could have sustained and how this estimate can vary depending on the applied taphonomic loss rate. By showing how these estimations can only be carried out on well preserved and appropriately excavated (using fine-mesh sieves) zooarchaeological assemblages, this paper discusses fish bone taphonomy and how aquatic resources can be connected to a general population increase and a sedentary lifestyle in southern Scandinavia.

By measuring the fish bones and using regression equations to calculate average sizes and weights to extrapolate the minimum number of individuals found for each fish species, estimations could be made of how much meat each species could have provided and the size distributions of the different fish species (Fig. 15).

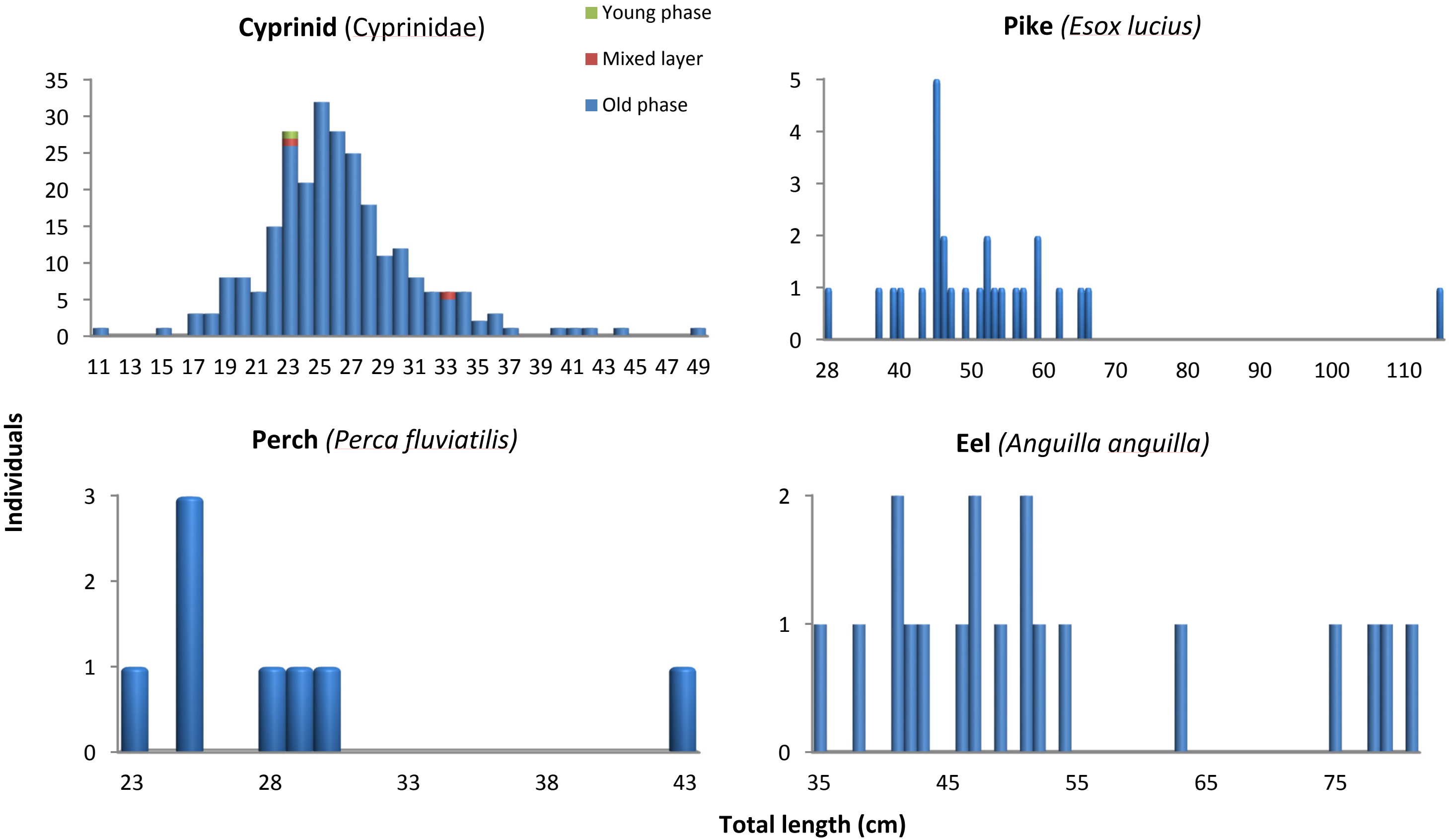

Figure 15 Size distributions for the four most common fish species at Norje Sunnansund. The cyprinids mainly consisted of roach, but the measurements were taken on a non-species determinable bone element, thus other cyprinid species are also represented. N: Cyprinids=257; Pike=27; Perch=8; Eel=19.

Fishing efforts were largely aimed towards cyprinids, as suggested by both the significantly larger numbers of cyprinid bones and the size variation of the species, which indicated that the cyprinids had been fished more throughout the year and not specifically during certain periods. The cyprinid fishing appeared to focus on fairly large roach, between roughly 17 and 34 cm in total length, with a peak between 22 and 28 cm. Roach reach sexual maturity between the ages of 3 and 5 years (Kullander et al., 2012) and at varying size, depending on the properties of the lake, as their growth is strongly related to their living environment, with reported sizes between 10 and 26 cm at 5 years of age (Curry-Lindahl, 1969). The relatively large size of the roach from Norje Sunnansund and their size distribution therefore suggests favourable living conditions for roach, and that mature roach were specifically targeted during a limited time of the year. Interestingly, in the cyprinid size distribution two size spikes are detectible in the otherwise unimodal distribution curve, one at 23 cm and one between 25 and 27 cm. This corresponds with mature roach and could indicate the size of roach as they gather for spawning activities. Furthermore, and although tentative and possibly an artefact of the limited sample size, measuring biases[42] or unknown taphonomic factors, the two spikes could indicate one catch peak during spring, when roach gather for their spawning activities, and a second larger catch event during the autumn, when roach can gather in large quantities to ‘fake’ spawn (Curry-Lindahl, 1969); in other words, when roach congregate before relocating to deeper waters where they spend the winter season (Bērziņš, 2010). Although the size distribution seems to indicate that mature roach were the focus of exploitation, the 2.5-mm sieves used on the excavation are still too large a mesh size to recover the smallest fish bones. Indeed, the smallest roach (Fig. 15) was found in one of the soil samples while using a sieve with a 0.4-mm mesh size, and the frequencies of the smallest fish (total length <15 cm) were not detectible with the methods used on the excavation.

Even though the size frequencies of the smallest fish cannot be properly investigated, the overall size distribution does indicate a targeting of sexually mature roach during two seasonal periods of aggregation. Furthermore, it is highly likely that these seasonal large catches were made with stationary fish traps, i.e. corresponding to those found at the contemporaneous Haväng site (Hansson et al., 2018). Alternatively, nets could have been used, e.g. something similar to the somewhat older Antrea Korpilahti fishing net from Karelia (Miettinen et al., 2008; Pälsi, 1920), which can be used both as gill nets (stationary) or seine nets (used to surround the fish) (Bērziņš, 2010) or in combination with some sort of hand-held net, which could have been used from either land and/or canoes. The large catches

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[42] The distribution curve is even more bimodal when based on the actual measurements instead of the calculated total length, wherein calculation biases do not affect the interpretation (cf. Appendix, Chapter 13.2).

yielded by roach aggregations could then be fermented and stored for use during other parts of the year.

The size estimations of the different fish species were recalculated to generate weight estimations and, consequently, calculations could then be made regarding how much fish meat the excavated bones represented. After the weight calculations had been made, estimates of taphonomic loss were applied to provide different scenarios based on different amounts of originally caught fish, albeit with large variations attributed to the different scenarios for estimated taphonomic loss. Once an estimated amount of originally caught fish had been generated, it was used to suggest the number of people that could have lived on those amounts of fish and for how long the fish could support them. However, it should be acknowledged that the results are broadly modelled. The estimations did not, e.g., include any mammal, bird or plant material in the calculations and, even though the modelled fish weight estimates were derived from quantified data, i.e. from exact measurements of individual fish bones, the end results cannot be viewed as equally exact. This is not the purpose of the paper, as a 'true' derivation cannot be made on these premises. Instead, the purpose of this paper is to illustrate the large effects of taphonomic loss, and the quantifications provide a basis for the discussions. In other words, the quantifications are presented to illustrate roughly the amount of caught fish and to make a point that cannot truly be made without numbers but can focus the discussion. This was done to avoid vague statements such as 'they had consumed a lot of fish', which does little for the understanding of fish bone taphonomy or for quantifying the amount of fish extracted. The paper should not be seen as attempting to strip away the taphonomic imprint of a bone assemblage or even to attempt a true reconstruction of the same. More accurately, the design of this paper is like an abstract painting, i.e. a focus to gather in front of to discuss and contemplate, but not to be taken literally; it is a paper designed to illuminate the potential in 'lost' information. Therefore, and going back to an earlier statement about attempting to use taphonomy to provide an alternative explanation for fish bones being absent on other sites, the paper provides arguments for large taphonomic losses even on 'unique' sites such as Norje Sunnansund. Consequently, the paper highlights the fact that taphonomy needs to be considered in depth in other contexts as well.

7.4. Paper IV – Huseby Klev and the quest for pioneer subsistence strategies

Paper IV deals with the west coast of Sweden by examination of a site, Huseby Klev, with large amounts of marine fish and marine mammals in the bone assemblage. Huseby Klev was excavated 25 years ago but the bone material had, prior to the author gaining access to it and supervising four bachelor students analysing it for their bachelor degree (Christensson, 2015; Hellgren, 2015; Nemecek, 2015; Widmark, 2015), only been summarily studied and preliminarily reported (Jonsson, 2005). Huseby Klev has yielded the most preserved organic material from marine environments from the Early Mesolithic period, it has the oldest preserved Scandinavian coastal bone material, and the site was occupied during three separate phases, which enables the study of chronological change. Therefore, the aim of this paper was to use this unique zooarchaeological assemblage and let it take centre stage in the debate regarding the Scandinavian pioneer settlers. By recognizing the potential of the bone material from Huseby Klev, the paper aims to advance our knowledge of the Scandinavian pioneers in marine environments and answer questions regarding their subsistence strategies, and how and why these strategies changed and developed over time.

While this might not seem to provide arguments for a freshwater fish diet, it does provide insight into the importance of aquatic resources. Both aquatic mammals and an abundant fish bone assemblage contributed to this interpretation. Furthermore, in paper IV it is suggested that the original methods used for extracting the marine fish and mammals had most likely evolved by applying freshwater fishing methods, i.e. without the use of advanced boats[43] or advanced marine fishing gear, and by hunting the marine mammals from the shore of narrow straits, thus suggesting an adaptation from freshwater fishing. By presenting arguments for a long tradition of freshwater fishing, from the Late Upper Palaeolithic onwards, and by discussing the general lack of Early Mesolithic

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[43] Although it is debatable what should be considered advanced, i.e. the people at Huseby Klev unquestionably had both functional and sturdy boats and were able to forage the ocean. This is indicated by the recovered fish species (of which some were probably not caught from the shore), the large number of bone fragments from auks (birds that would probably have been caught on unpopulated islands or herded ashore with the use of boats (Bengtson 1984)) and, arguably, by using boats to herd dolphins into narrow straights to be killed from the shore. However, as discussed by Pickard and Bonsall (2004), there is no clear evidence that the fish species found on Mesolithic sites could not have been caught inshore (within 5 km from land) and no other evidence supports an economy based on offshore/open sea deep-water fishing. While this conclusion might change with a complete analysis of the fish bones from Huseby Klev, currently the interpretation is that the available boats were probably not designed for offshore deep-water foraging and thus, if classified according to a distinction between offshore and inshore boats, are not considered to be 'advanced'.

coastal sites with preserved organic remains, the results from Huseby Klev, regarding the methods used for maritime adaptation, therefore suggest an origin in freshwater fishing methods. Furthermore, based on the sharp decline in marine mammal bones in the bone assemblages from the initial occupation phase to later phases (Fig. 16), with a corresponding increase in fish bone abundance[44], it is argued that the area around the west coast became densely populated during the initial Holocene. This was possible because of high bioproductivity in the ocean, as a result of melt water from the melting ice sheet adding nutrients from terrestrial sources into the ocean (cf. paper IV for a full discussion).

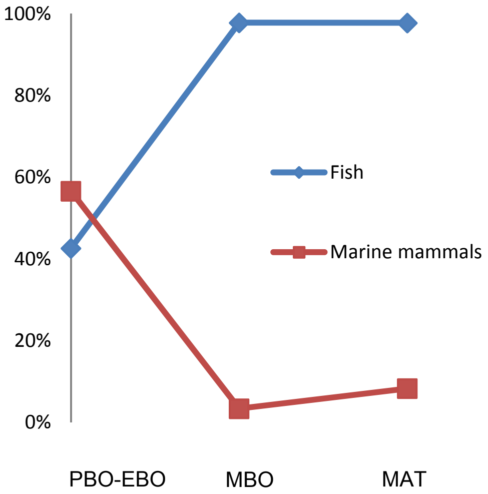

Figure 16 Frequency of fish and marine mammals between the different phases at Huseby Klev. For marine mammals, based on a comparison of NISP between marine mammal bones and the total amount of mammal bones. For fish, the comparison is based on ENISP for fish in comparison with NISP from all mammals and birds[45]. Total number of fragments as follows. NISP mammals: PBO-EBO=364; MBO=149; MAT=169. NISP birds: PBO-EBO=77; MBO=50; MAT=15. ENISP fish: PBO–EBO=327; MBO=8782; MAT=7939 (for specific data see paper IV). Regarding the abundance of fish bones during the PBO–EBO phase it should be recognized that less effort was made to fine mesh sieve the soil from this context (Jonsson pers. comm.), so it is conceivable, but not confirmed, that fish bones in the PBO–EBO period might have originally been somewhat more common than they appear in the recovered bone assemblage.

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[44] It should be acknowledged that quantitative comparisons are somewhat problematic and complicate interpretations. This is because of differences in the taphonomic history, such as an extra effort directed at fine mesh sieving the layers from the MBO phase (Jonsson pers. comm.), which resulted in an increase in small fish bones, i.e. herring bones (see fig. 19); slightly more gnawing marks on the PBO-EBO bones, suggesting more destruction from dogs during this phase; and a varying prevalence of fluvial abrasion on the bones from the different phases (24% during the PBO–EBO phase, 41% in the MBO phase and 16 % during the MAT), which suggests varying degrees of transportation and an increased loss of small fish bones with increased fluvial activity.

[45] As argued in paper IV, ENISP can be compared with NISP in order to illustrate patterns that would have been visible if the entire bone assemblage had been analysed (see Quantification, Chapter 6.1.2).

Suggestions of a densely populated area is further strengthened by the large number of Early Mesolithic sites recovered on the coast of Bohuslän in western Sweden (Schmitt et al., 2006). Nutrient-rich marine waters are considered to have created optimal environments for marine life and, consequently, a population boom in top predators such as whales and seals. As the increased bioproductivity ceased in the ocean, it is suggested that the zooarchaeological record indicates the human population continued to harvest marine mammals, and the marine mammal populations consequently declined, resulting in a human shift in subsistence strategies. The importance of marine fish would then have increased even further. However, it can also be argued that the osteological remains from the different phases represent different types of occupation or that the observed decline in marine mammal bone prevalence represents different types of depositions. Although plausible, these alternatives do not provide the most likely explanation. For example, when studying the species diversity across the three different settlement depositions, they appear to be roughly similar; the somewhat higher species diversity during PBO–EBO is probably because more effort was made to identify the bird bones (Fig. 17 left). Furthermore, while there is some terrestrial species variation between the different phases, nothing appears to indicate active sorting of the bone material, which would indicate that marine mammals are largely missing from the younger phases for this reason (Fig. 17 mid, right).

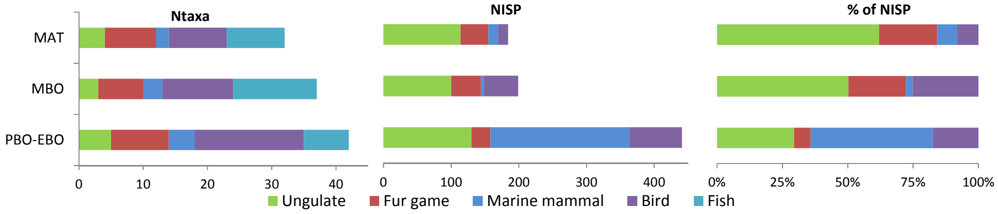

Figure 17 Number of species within each animal category (left), number of identified specimens (mid) and animal category proportion, based on NISP (right), from the three different phases at Huseby Klev. Fish NISP not included in middle and right figure due to partial analysis.

Regarding the element distribution (cf. Appendix, Chapter 13.3 for detailed information), there appear to be some differences; the youngest phase appears to differ from the two earlier phases with a much larger proportion of skull fragments from both ungulate and seal species. This could be because of differential handling of the prey or because of variations in the utilization of the bone material. However, as only small differences in element distribution are detectible between PBO–EBO and MBO, and the major drop in marine mammal bones is found between the two earliest phases (seals are slightly more prevalent during MAT compared with MBO), it is difficult to relate the low numbers of marine mammal bones in the two later phases to variations in how the animals (or their bone remains) were handled. Furthermore, the largest differences in element distribution are found among the marine mammal bones, where the oldest phase is dominated by body core fragments, i.e. mainly by bones from the vertebral column (Fig. 18) from the two dolphin species, and the entire seal skeleton is represented[46]. During the mid-occupation phase, the few available dolphin bones[47] are also mainly body core fragments, while there is only one seal limb bone.

Figure 18 Vertebra from a white beaked dolphin from the PBO–EBO phase of Huseby Klev. Photo: Adam Boethius.

During the youngest phase, the seal bones are almost exclusively cranial fragments and no dolphin bone could be identified (see paper IV). Overall, most differences between the phases are related to marine mammals (Fig. 17) and fish[48] (Fig. 19). This, in turn, suggests that either the marine mammal population moved further north, and humans intensified their fishing as a response to the marine mammal movement, or that the heavy marine mammal exploitation seen in the PBO–EBO

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[46] Mainly because whales having regressed and rudimentary extremities, as an aquatic adaptation, while seal extremities are larger and sturdier and allow terrestrial movement.

[47] Four dolphin bone fragments could be identified from the MBO phase, compared with 167 dolphin bones from PBO–EBO.

[48] However, it is difficult to interpret the fish bone assemblages because only small amounts of the material from the two youngest phases have been analysed; thus ENISP extrapolations have largely been used to interpret the importance of fish.

phase[49] resulted in a local population decrease and the human population was forced to intensify their fishing or move to new areas. Given that both harbour porpoise and white beaked dolphins are considered fairly regular, albeit often seasonal (Weir et al., 2007), species in, e.g., the North Sea today (Hammond et al., 2002; Northridge et al., 1995), it is unlikely that they would have completely abandoned the area along the west coast of Sweden during the Early Holocene without provocation. The same is true regarding both grey seals and harbour seals, as they often return to breed at their natal sites (Pomeroy et al., 2000) and can be classified as relatively stationary species (Härkönen et al., 2006).

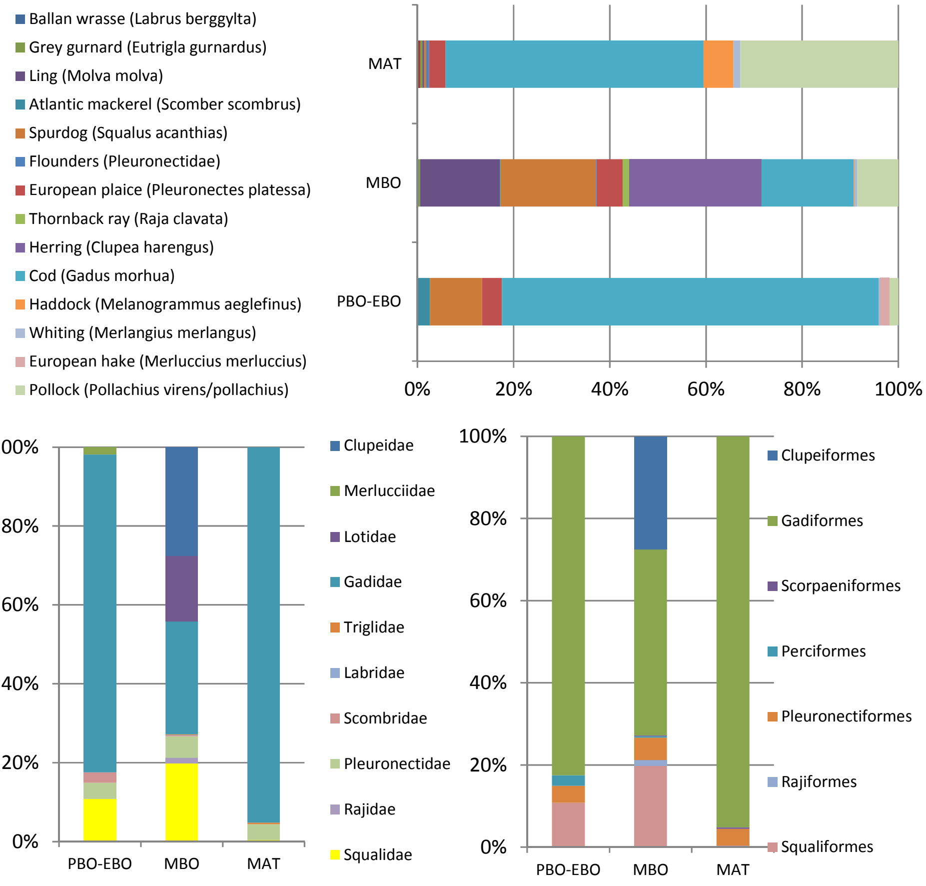

Figure 19 Identified fish bones from the three phases at Huseby Klev; species (upper), family (lower left) and order (lower right).

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[49] This is also hinted at by the large number of contemporaneous, or older, sites located on the Swedish west coast (Schmitt et al., 2006), although they unfortunately lack organic remains.

Epidemic outbreaks can strongly decimate the population size of a selected species in a given area, e.g. as seen in the 1988 and 2002 North European harbour seal epidemic outbreaks (Härkönen et al., 2006). However, epizootic outbreaks do not affect different species equally; it is rare for a virus to cause an epidemic in a new host species[50] (Parrish et al., 2008) and even more so in many different species at once. Because of the observed pattern at Huseby Klev and the suggested implication for other older or contemporaneous settlements in the area, it is more likely that human exploitation affected the dolphin and seal populations and initiated the observed marine mammal decline. Accordingly, the human capacity to overexploit a species is something that not only has to be considered in a terrestrial setting but also in aquatic environments. For example, see the discussions for and against the role of humans in the extinction of mega-fauna on the American continents (Barnosky, 1989; Barnosky and Lindsey, 2010; Johnson et al., 2013; Lima-Ribeiro, 2013; Lima-Ribeiro and Diniz-Filho, 2013) and Australia (Brook and Johnson, 2006; Rule et al., 2012; Westaway et al., 2017) or, in a more local context, the extinction of the Scandinavian aurochs during the Middle Mesolithic period (Aaris-Sørensen, 1980; Ekström, 1993; Magnell, 2017; Noe-Nygaard, 1995; Noe-Nygaard et al., 2005).

The results from Huseby Klev suggest that Norje Sunnansund was not unique among Early Mesolithic communities and certainly not the place from where a dependency on aquatic resources emerged, the oldest phase of Huseby Klev being somewhat earlier than Norje Sunnansund. The reason why evidence of humans in marine environments from and prior to the Early Mesolithic period is lacking in archaeology is because the former coastline (and consequently all plausible coastal settlements) is now largely located at the bottom of the ocean. However, the areas around Bohuslän and the west coast of Norway[51] are among the few locations in Europe where the ancient coastline has been preserved (because of an isostatic land rise corresponding with a sea level rise in this area). The transgression after the last ice age put all other ancient European (west) coastlines far out into the Atlantic and they are, consequently, inaccessible to regular archaeological excavations, although marine archaeological excavations of submerged sites are possible (Fischer, 1995; Fischer et al., 1987; Hansson et al., 2018).

The material from Huseby Klev serves as a contemporaneous indicator for Norje Sunnansund, highlighting the importance of aquatic resources during the Early

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[50] Most viral host transfers to new hosts cause only single infections or limited outbreaks, which is fortunate, as an epidemic or epizootic outbreak can have dire consequences for a new host species (Parrish et al., 2008).

[51] Although only small amounts of organic remains have been preserved from Early and Middle Mesolithic Norway because of the acidity of the Norwegian soil, which complicates discussions of human subsistence strategies.

Mesolithic. The known Early Mesolithic coastal sites with preserved organic material indicate a maritime-dependent lifestyle, implying that this might be the norm in this type of environment. Although this is not in itself a bold statement, as it has long been recognized that the Early Mesolithic settlers on the Scandinavian west coast must have relied heavily on marine resources (Bjerck, 2009), it does, as already mentioned, provide an insight such that the methods of utilizing the marine species are initially reminiscent of the methods used for catching fish in freshwater environments.

7.5. Paper V – The importance of freshwater fish in Early Holocene subsistence

The paper on Huseby Klev provides a contemporaneous site for Norje Sunnansund where an aquatic diet can be inferred. However, various methods had to be used to show that taphonomy is a major factor explaining why archaeological researchers to date have not been able to recognize the full extent of the importance of freshwater fish in the Early Mesolithic diet. Therefore, in paper V, the aim was to examine further the importance of freshwater fish to Early Holocene foraging societies. This was done by examining the colonization of the island of Gotland, in the Baltic Sea. By studying the freshwater reservoir effect on a number of radiocarbon dates and by presenting evidence from a recent excavation of the Early Mesolithic site Gisslause, the paper aimed to connect these two lines of evidence and to reconsider the importance of freshwater fish and advocate the use of alternative methods to reveal these elusive dietary indications.

In previous research on Gotland, seal hunting and maritime subsistence strategies have been seen as the major pull factor, attracting the pioneer settlers to the island (Andersson, 2016; Clark, 1976; Lindqvist and Possnert, 1999; Österholm, 1989; Pira, 1926; Schnittger and Rydh, 1940). To claim that this was not the case, and that taphonomic loss is responsible for a lack of consideration of freshwater fishing, the same narratives were used as in the discussions of the Swedish mainland sites.

A two-pronged approach was used to illustrate the importance of freshwater fish in the human diet. First, it is argued that fish bones have not been recovered from the few available sites because of a lack of sieving, which is the same argument proposed earlier regarding mainland contemporaneous settlements. This claim is strengthened by including a recently excavated Early Mesolithic site from Gotland, Gisslause. Here five 1m^2 squares were excavated and fine-mesh water sieved (down to a 2-mm mesh size), which generated a relatively large number of fish bones from freshwater species. The fish bones were dominated by elements from burbot and cyprininds (Fig. 20) that, because of the seasonal behaviour of the burbot[52], also indicated site occupation during the winter, which was unknown from Early Mesolithic mainland southern Scandinavia (Carter, 2001; Magnell, Submitted-a; Rowley-Conwy, 1993; 1999) prior to the discovery of Norje Sunnansund. Because of the excavation of Gisslause, it is proposed that if fine-mesh water sieving is applied at well-preserved Early Mesolithic sites, fish bones will be abundant. Also, as only 5m^2 were excavated using water sieving, these results could be compared with those from the preliminary excavation of Norje Sunnansund, where 3m^2 were excavated (Boethius and Magnell, 2010). The amount of fish bone from the preliminary excavation of Norje Sunnansund could be compared with the 5m^2 excavated on Gisslause, bearing in mind the results from the final excavation of Norje Sunnansund, when 842 excavation units (totalling 647m^2) were water sieved and close to 200,000 fish bones recovered.

Figure 20 Vertebra from burbot (left) and part of pharyngeal bone from a cyprinid (right) from Gisslause. Photo: Adam Boethius.

Secondly, radiocarbon dating was used to investigate the importance of freshwater fish. Human collagen was systematically older than all the other dated organic material from Gotland. This suggested a freshwater (also known as hard-water) reservoir effect, i.e. the difference between the age of freshwater carbon reservoirs and the age of atmospheric, terrestrial and marine carbon reservoirs (Ascough et al., 2010; Coularis et al., 2016; Philippsen, 2013). A freshwater reservoir effect is seen in animals living in ^{14}C-depleted lakes, and consequently humans if they are consuming those freshwater-living animals, e.g. freshwater fish (Philippsen, 2012; 2013). Therefore, the radiocarbon dates suggested a large input from freshwater fish in the diet of the human pioneering inhabitants of Gotland. The results from paper V indicate a subsistence based on freshwater fish and, at the same time, strengthen the argument that as soon as an Early Mesolithic site from a freshwater environment (with favourable preservation conditions) is subjected to water sieving, freshwater fish bones will occur frequently.

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[52] Burbots are traditionally fished during winter, when they are active during daylight as they gather in shallow waters to spawn. During the rest of the year they are nocturnally active and reside in the deepest areas of a lake (Kullander et al., 2012).

7.6. Paper VI – Fish and resilience among Early Holocene foragers of southern Scandinavia

The last paper to address the importance of aquatic resources uses stable isotopes in human bone collagen. In this concluding paper of the thesis, the aim is to provide a wider perspective on the diet of Early and Middle Mesolithic Scandinavian foragers and clarify if, and how, source-specific dietary estimations can enhance our understanding of their subsistence strategies. This is done by illustrating the importance of individual protein sources in both general (within an environmental and temporal framework) and site-specific diet estimations.

In order to cope with the overlapping baselines from freshwater and terrestrial dietary sources, a Bayesian diet mixing model was applied to the data. The process is described in detail in the Methods (Chapter 6.3.2) and in paper VI, but in general terms it was used to assess the most likely diet combinations resulting in the observed human $\delta^{13}C$ and $\delta^{15}N$ values. To assess the importance of different dietary sources, available Mesolithic isotope data were gathered and an additional 419 bone samples from contemporaneous sites were sent for isotope analysis, which resulted in 186 new values that could be added; a total number of 378 stable isotopes values were included in the analysis (Fig. 21).

The human isotope signals were divided into four different categories, depending on time period (Early and Middle Mesolithic) and living environment (freshwater and marine). By running the data uniformly (without adding additional information) it could be shown that aquatic resources (fish and seal) dominated the protein intake of the diet. However, to get a higher resolution, zooarchaeological data from the three main Early Mesolithic sites investigated in the thesis were also added, i.e. data from Norje Sunnansund, Huseby Klev and Gisslause (papers II, IV and V). By adding this information, inserted into a framework based on ethnographic accounts of forager data and their general dietary input from different types of subsistence strategies according to Marlowe (2005)[53], in combination with the human isotope data from these three sites and contemporaneous dietary source isotope data, it was possible to derive estimates of the importance of each food source to the general protein diet at the different sites. The results, once again, highlighted the importance of aquatic resources but also showed a large site-specific dietary variation. By combining the data from the site-specific informative analysis with the uniform analysis and a diet niche reconstruction, it was shown that the 'general' Early and Middle Mesolithic diet was largely based on fish, with a temporal diet homogenization from the Early to the Middle Mesolithic period. This, in turn, was interpreted as fish becoming increasingly important and contributing to lower residential mobility rates, indicating that mobility might not be the only risk reducing subsistence strategy available.

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[53] With corrections made to account for variations in the amount of protein in the different food sources.

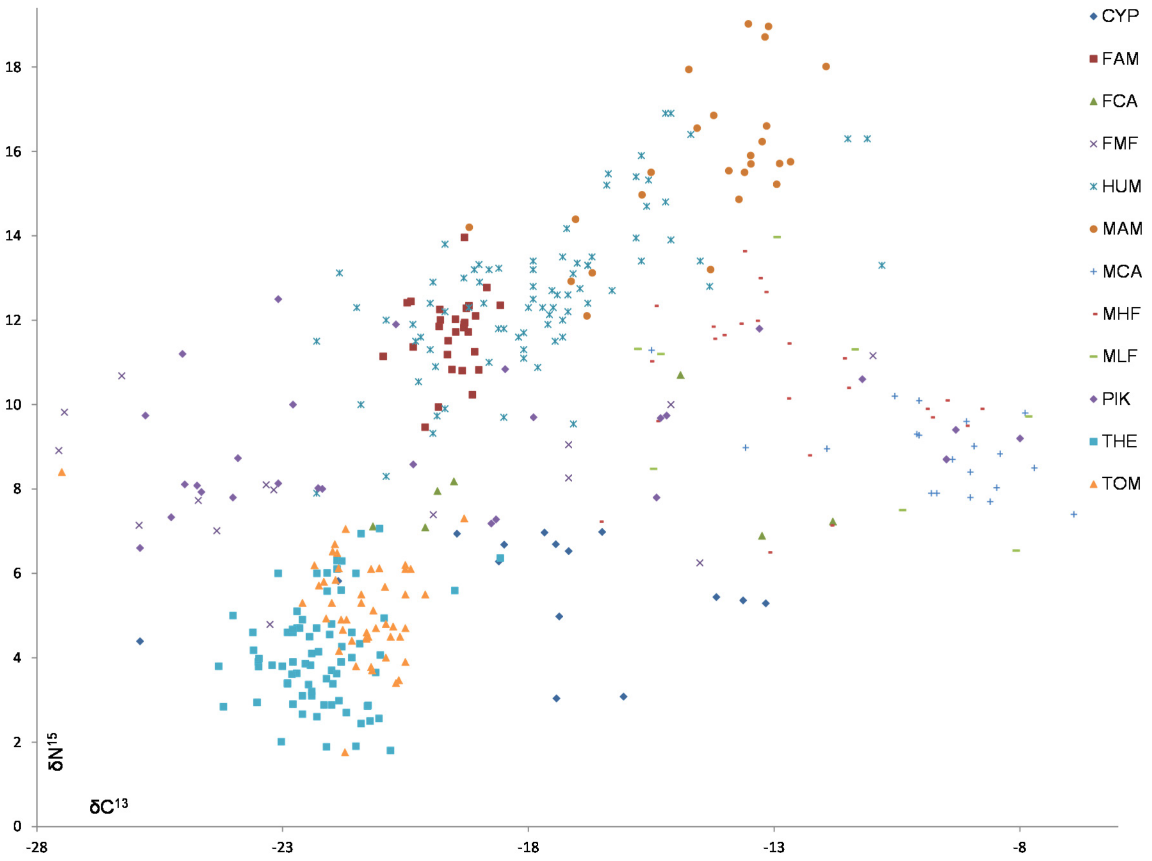

Figure 21 A bivariate graph of all known Scandinavian Early and Middle Mesolithic foragers and the available dietary source data, illustrated as the original δ^{13}C and δ^{15}N values without added fractionation factors. CYP=cyprinid; FAM= freshwater aquatic mammal; FCA=freshwater catadromous/anadromous fish; FMF=freshwater mid-trophic fish; HUM=human; MAM=marine aquatic mammal; MCA= marine catadromous/anadromous fish; MHF=marine high trophic fish; MLF=marine low trophic fish; PIK=northern pike; THE= terrestrial herbivore; TOM=terrestrial omnivore. Data available in paper VI, supplementary data 2 and 3.

8. Discussion: Implications of an integrated zooarchaeology, interpreting the Early Holocene societies of southern Scandinavia

This thesis has been written with a rather ambitious goal. By interpreting and integrating zooarchaeological material from Early and Middle Mesolithic sites, the aim has been to steer the discussions away from simple ‘bone lists’ or ‘hunted animals at a site’ results and instead to highlight the implications of the recovered bone remains. This has not been done because the more quantitative descriptions of a bone assemblage are wrong, they do have a purpose, but because of the need to emphasize the importance of being able to maximize the potential implications of the bone remains on the few precious sites where they are available. Far too many osteological remains have been left unanalysed or, after an analysis has been made, the interpretations left to someone other than the osteologist who carried out the analysis, with the consequence that the full potential of the bones is therefore not recognized. As so much in archaeological research is dependent on various taphonomic processes, it is important that, if an archaeological site is found with good organic preservation, those sites and materials should be treated with some priority. As with the results presented above, exploring the zooarchaeological remains from a site fully will enable comparisons, parallels and analogies to be drawn with sites that do not show equal preservation, i.e. where only inorganic remains have been found. As the latter types of site are much more frequent than sites with organic preservation, sites with preserved bone material become even more important if properly excavated, analysed and interpreted, because they can function as a bridge between organically deprived sites and sites with organic material, i.e. they can advance interpretations of whole cultures and time periods. Given the results presented in the six different papers, it is now possible to discuss Early and Middle Mesolithic societies in broader terms and to draw new conclusions. The windows into these societies created with the recovery of zooarchaeological remains that have been allowed to function beyond being a supplement to the overall archaeological interpretations, have the potential to take centre stage in the discussions of Early Holocene life and subsistence.

8.1. Tracing complexity

In anthropologic research, complexity among foragers has previously often been considered an anomaly (Fitzhugh, 2003:4). This is perhaps because those foraging societies available for study during the last few hundred years have largely been pushed into marginal areas, so studies and research on foragers have been based mainly on egalitarian small-scale societies[54], which previously were taken to stand as examples of pre-farming communities. However, during the last 40 years or so, complexity among foragers has attracted more attention in anthropologic research, and questions of why complexity among foragers evolves is a frequently occurring theme (cf. Research history, Chapter 3.1.2). It has been suggested that complexity can develop when certain criteria are met, such as population pressure, temporal and spatial resource abundance, developed storage systems, labour control and tribal warfare (Ames, 1981; Burley, 1980; Fitzhugh, 2003; Schalk, 1981; Testart, 1982). Furthermore, seasonal variation has been suggested as a causal factor both because it requires coordination if it is to be optimally exploited, but also because the resource extraction points occur sporadically in the landscape and control of them becomes essential for survival, as they provide the means of creating a store that can last throughout the leaner months of the year (Ames, 1985; Kelly, 1991; Matson, 1992). Therefore, researchers often stress the importance of aquatic resources in the development of complex foragers (Ames, 1994).

Given the biased nature of archaeological remains, the above stated criteria cannot all be studied. In this thesis, it has been possible to argue confidently for the

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[54] In Scandinavia, the Sami populations have e.g. been referred to as egalitarian foraging societies prior to becoming more heavily reliant on reindeer herding, which in some areas is thought to have occurred in the 17th century (Mulk, 1994). In other areas of northern Scandinavia, the reindeer herding tradition has been proposed as a factor that increased the mobility of the Sami groups into something referred to as semi-nomadism, and ‘Sami’ settlements have been suggested located mainly on lake shores during the Bronze Age and Early Iron Age, but in the Late Iron Age mainly at inland locations, reflecting a transition to a semi-nomadic reindeer herding economy (Hedman, 2003:220f). A transition to a pastoral economy is also suggested as a cause of Sami societies becoming driven by capitalism in response to increasing demands for furs and skins (Hedman, 2003). Some historians have suggested this is a rather late phenomenon, dated to around the 17th century (Lundmark, 1982), but most researchers place the domestication of reindeer further back in time (Fjellström, 1986), e.g. to the Late Iron Age (Hedman, 2003). Regardless of when reindeer domestication began, it was held in greater esteem than e.g. fishing from at least the 17th century onwards. Historical accounts from the late 17th century suggest that while different types of Sami existed (e.g. lake, forest and mountain Sami), the forest and lake Sami, who lived mainly on fish, were regarded as poor in comparison to the reindeer-owning mountain communities (Fjellström, 1986:118-120). Nevertheless, and even though reindeer husbandry, hunting, gathering and fishing would probably have been used simultaneously within groups of Sami people until the 19th century (Bjørklund, 2013), because of the developed reindeer husbandry at the time ethnographic accounts were gathered, the Sami foraging origin (and its suggested egalitarianism) is problematic for study through ethnographic accounts.

abundance of freshwater fish (paper III), a high reliance on freshwater fish (papers I, II, III, V and VI) or on marine aquatic resources (paper IV and VI), the creation of large-scale storage facilities (paper I), evidence of population pressure through indirect analogies (paper II, III, and IV) and the presence of year-round seasonality indicators (paper II). However, the areas most related to complexity among foragers, such as stratified societies (e.g. labour control, slavery and autocratic leadership) and tribal warfare, elude us. Furthermore, complexity itself might be subject to increasing taphonomic loss, considering that complex displays among ethnographically complex societies are often based on highly elusive information, such as oral traditions, leadership, central commands, slavery, organic remains and wooden structures. The older a material gets, the more it is subject to taphonomic losses, and the Early Mesolithic period is additionally biased for many reasons. The sites are highly elusive and difficult to find; if organic remains are preserved they will have been covered by sediments from a transgression or other type of sedimentation process shortly after or during the occupation of a settlement, which makes the sites even more difficult to recover. Early Holocene coastal areas are in general completely lost because they are now submerged. Organic material (plant fibres, wood and bone, etc.) rarely survives, and population densities are highly elusive and difficult to study.

8.2. Tracking variability and territoriality

The level of complexity among foragers in coastal areas has long been debated, and a high level of complexity and social stratification have been suggested for the Late Mesolithic foragers in southern Scandinavia (Price, 1985; Rowley-Conwy, 1983). Furthermore, territoriality is often considered a signal of complexity among foraging societies (Price and Brown, 1985a). However, territoriality occurs varyingly in a landscape and, regarding the models put forward by Rowley-Conwy and Piper (2016), it is suggested that northern coastal areas differ from many other environmental types and have rarely been considered among earlier forager research, typologies and models. The conclusions drawn from the above mentioned study of foragers are multi-layered. For example, Rowley-Conwy and Piper (2016) show a high degree of variability in complexity, social hierarchy, sedentism and population density among varied groups on the north-west coast of America. This variability is connected with resource availability and predictability, where groups with an abundance of resources do not practice any resource ownership or emphasize descendent inheritance, similar to groups with low resource availability without predictability. However, groups with seasonal abundance with high predictability instead practise more resource control, more social stratification and inheritance to descendants (Rowley-Conwy and Piper, 2016:7) (Fig. 22).

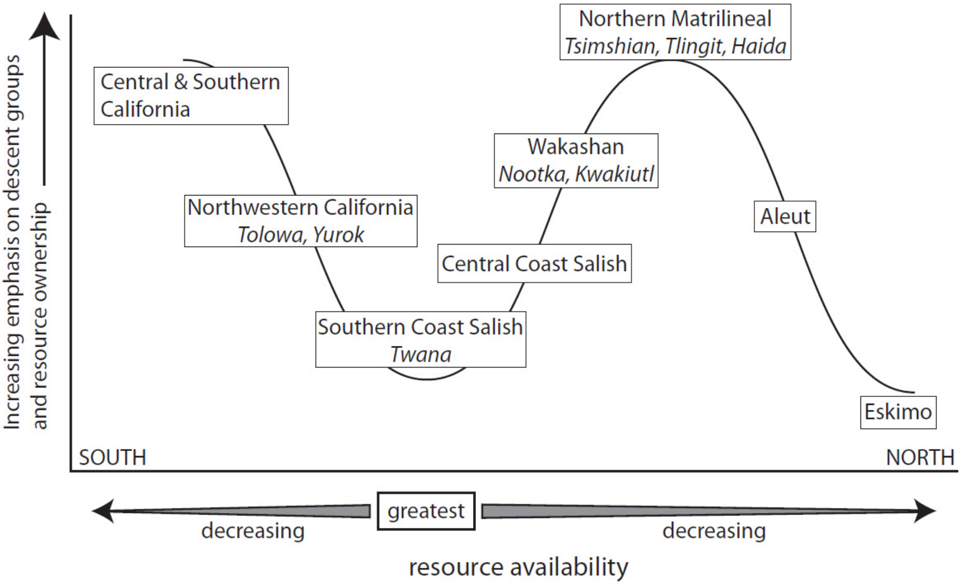

Figure 22 Correlation of degree of resource ownership by descent groups and latitudinal variation among foragers on the coast of North America. Figure originally in Rowley-Conwy and Piper 2016 and reproduced with the authors' permission.

On the other side of the Pacific Ocean, and on somewhat lower latitudes, a reliance on salmon (*Oncorhynchus* sp.) has supported a group of foragers commonly considered both complex and sedentary (Hudson, 2014), i.e. the Ainu people from northern Japan. Although no first-hand ethnographic accounts of their traditional lifestyle are available, archaeological evidence together with both historical records from Japan and interviews with Ainu elders have provided a great deal of information regarding their subsistence strategies, trade, seasonal activities and settlement patterns. These sources indicate stratified societies where chiefs had control over limited territories, e.g. villages, and where slavery was a part of their way of life (Hudson, 2014). Similar to the variability noted among the populations of the north-west coast of America, there seem to have been regional variations among the Ainu as well. In general the Ainu from the island of Hokkaido are considered to have lived a more affluent and sedentary lifestyle, compared with the Ainu from both Sakhalin and the Kuril islands (Hudson, 2014). Furthermore, and related to variability as a result of resource availability, suggestions have been made that the level of Ainu territoriality increased after Japanese commercial interest greatly reduced the abundance of salmon in coastal areas by using large drifting nets in the river mouths (Ōnishi, 2014). It is suggested that the commercial fishing exhausted the Ainu's most reliant resource, which in turn forced the Ainu into certain areas and to become even more territorial as a response to predictable key resources becoming less abundant (Ōnishi, 2014).

The account presented above suggests that it is also important to consider a large variety of cultural expression among the human societies of southern Scandinavia during the Early Holocene. However, it is debatable to what degree information about variability among ethnographic foragers from North America or Japan can help the interpretation of long-lost ancient foraging communities in northern Europe. It is not possible to translate latitude directly, as unique local environments and circumstances generate local prerequisites for subsistence strategies and life choices. Even so, comparisons can be made even if absolute analogies cannot be drawn. When comparing latitudes, southern Scandinavia is located around 55–59°N, which corresponds roughly with the western coast of Canada and the south-western tip of Alaska, in which some of the most territorial and socially stratified tribes on the west coast of America traditionally reside: the Tlingit, Haida and Tsimshian. These societies have often been characterized as fiercely territorial and highly reliant on the annual salmon runs to store and secure a food supply throughout the winter and enable a sedentary (or semi-sedentary, depending on how sedentism is defined) lifestyle (Ames, 1994).

8.3. The (un)importance of salmon

The importance of salmon (*Salmo salar*) has been discussed in north European prehistoric contexts (Carlsson, 2008). However, the actual evidence of salmon dependency has been harder to find, mainly because salmon bones are often lacking in the zooarchaeological record. This lack of salmon bones has been discussed in terms of increased taphonomic loss compared with other fish species. This, in turn, has been suggested to be because i) salmon have a structurally weaker skeleton compared with other fish species (Desautels et al., 1970); ii) rodents or dogs have consumed the salmon bones; iii) salmon was prepared in a way that rendered only small salmonid fragments (Casteel, 1976b); or, lastly, iv) bones from fatty fish species possibly suffer from increased diagenetic decay (Lepiksaar et al., 1977). When addressing these issues it should be acknowledged that the cranial skeleton of salmonids is less dense than the vertebral column (Butler and Chatters, 1994). Consequently, the cranial bones are subject to an increased destruction rate (Lubinski, 1996). In addition, salmon resorb the calcium in their skull as they enter freshwater rivers and prepare to spawn (Wheeler, 1978). However, the same cannot be said about the vertebral column, which has not been reported to be significantly altered during the spawning process. Furthermore, although it is conceivable that dogs prefer fatty over lean fish, other fatty fish species often appear in large numbers. Eel, e.g., are common at Late Mesolithic sites, such as Norsminde (Enghoff, 1989) and Krabbesholm (Enghoff, 2011), and herring often appear in large quantities in marine contexts where fine-mesh sieves have been applied, such as at Krabbesholm (Enghoff, 2011), Tågerup (Eriksson and Magnell, 2001) and the Mid-Boreal phase of Huseby Klev (paper IV). In addition, bones from both salmon and trout have long been known at Late Palaeolithic sites from both southern Europe and Russia (see e.g. Clark, 1948 and references therein) and have here been observed to occur in high frequencies (Russ and Jones, 2009). Salmonids have been found at numerous sites in North America, even in contexts where salmon bones had been crushed, when fine-mesh sieving was applied (Casteel, 1976b:90), as carried out at Norje Sunnansund and many Late Mesolithic assemblages (Enghoff, 1989; 1991; 1994; 1995; 2011; Enghoff et al., 2007; Ritchie, 2010). Salmon bones have also appeared in large quantities on many Japanese sites, from the incipient Jomon period (around 14–11 ka cal. BP) onwards, when fine-mesh water sieving was applied during excavation (Matsui, 1996). Lastly, Rebecca Nicholson has, in controlled experiments, shown that no accelerated bone decay is detectible on fatty fish species (Nicholson, 1992; 1996).

Salmon is present in Scandinavian Early Mesolithic contexts, e.g. in the Stora Förvar cave on Gotland, where a limited number of salmon bones were identified in the oldest layers of the cave (see the radiocarbon dates in the supplementary material of paper V). Salmon is also present at Norje Sunnansund, which, with the current shoreline, is located only 7 km from Sweden's most famous salmon river of today, Mörrumsån, if traveling by boat (about 11 km by land)[55], albeit in very small quantities[56]. In addition, on all other Early or Middle Mesolithic sites with preserved bone material, salmon is either completely absent, such as at Gisslause, Huseby Klev, Ageröd, Segebro, Ulkestrup Lyng, Sværdborg, Lundby, Kongemose, Mullerup, etc., or present in low quantities, such as at Tågerup (2% of the identified fish bones) and Ringsjöholm (2‰ of the identified fish bones). Salmon does occur at many Late Mesolithic sites, but always in very low frequencies (Enghoff, 2011:278; Rowley-Conwy and Zvelebil, 1989). Thus salmon appears to have been of low dietary importance in Scandinavia throughout the Mesolithic. The cause of this is debatable. Given the importance of migrating salmonids to humans residing in spawning areas, it is likely that they would have been equally exploited if similar conditions existed in the Scandinavian Mesolithic. It should also be considered that sites close to spawning areas today, e.g. Norje Sunnansund, should have more salmon bones if they were locally available. However, most of the best excavated sites that display good preservation and where fine-mesh sieving was applied, i.e. the Danish Late Mesolithic sites, are

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[55] 9000 years ago it would have been an even shorter distance between the river mouth of Mörrumsån and the location of Norje Sunnansund, because of the shoreline displacement (Hansson et al., Manuscript).

[56] Of 16,138 identified fish bone fragments, only one fragment could be determined as salmon, one fragment as trout and seven fragments as indeterminable salmonids, migrating salmonids thus representing less than a per mil (0.6‰) of the identified fish bones from the site.

not located in areas of modern salmon runs and should logically not include an abundance of salmon bones. Therefore, considering the rarity of salmon in Scandinavian Mesolithic contexts, and if the salmon were not systematically prepared differently compared with all other fish species (in a process that completely destroyed all their bones) throughout the entire Mesolithic period, two scenarios are plausible.

I. Salmon and sea trout runs, as they are known today, might not have existed, even though these salmonids did exist in early Scandinavian waters, as suggested by microsatellite DNA variation among modern salmon populations, which indicate that the Baltic Sea area was colonized on three different occasions during the end of the last glacial period (Säisä et al., 2005). This scenario suggests that, in spite of the regularity of salmon, which normally breed where they were born, the salmon runs have changed over the last 9000 years. This could be because of the ice sheet that covered the area for thousands of years: despite the area had been free from ice for subsequent thousands of years, e.g. at Norje Sunnansund for about 4000 years, salmon had not yet established a spawning route.

II. Salmon runs corresponding to modern ones did exist but the archaeological remains of the people that exploited them have not been found. This would imply that that the organic remains from these sites have not been preserved and that no trade in salmon existed between these and other groups located in areas with favourable preservation conditions. This could be because they had no means of preserving the fish, which seems highly unlikely given the evidence from Mesolithic Ireland, where large amounts of salmon preservation, by means of drying, have been suggested (Woodman, 1985a; b). Furthermore, people in southern Scandinavia were able to conserve fish by means of fermentation, which can be applied equally to salmonids and is ethnographically well documented (Stopp, 2002). Indications of long-distance interaction between different groups of people are seen in the archaeological material (Bergsvik and David, 2015; Damlien et al., 2018; David and Kjällquist, 2018; Sørensen et al., 2013). The presence of this contact but lack of salmonids would indicate interaction without transport of food products, e.g. because long-distance contact did not facilitate the transportation of stored salmon, or because low frequencies of salmon have not left any trace in the archaeological record. Following this scenario, even if salmonids were present in large quantities, they must have been spawning further north, where preservation is not optimal for bones and where only small amounts of burnt bone fragments are normally found from Stone Age sites or in remote rivers

> and lakes to the east of the Baltic Sea[57], i.e. in areas where the practicalities of exchange of large quantities of stored food hindered an effective spread of salmon bones. For this reason it is unlikely that Mörrumsån had been established as a spawning ground during the Early Holocene[58]. This also applies to sites such as Motala, located next to Lake Vättern in the northern part of southern Sweden, which, given the above arguments, if salmon were present in large quantities and salmon runs had been established corresponding with those documented in modern and historical times, should display large quantities of salmon bones but do not (Gummesson et al., Manuscript).

Therefore, regardless of the reason for the lack of salmonids in southern Scandinavian Early Holocene contexts, the importance of salmon to the corresponding human societies must have been limited. Thus it is fundamental to examine whether subsistence strategies, other than those based on salmon migrations, could generate large enough quantities of food to instigate lower residential mobility, agglomeration and growing populations, i.e. increasing sedentism and territoriality in Mesolithic Scandinavia.

8.3.1. And if not salmon

As demonstrated above, a high dependency on aquatic resources is often connected with anadromous fish runs, creating a seasonal abundance. Anadromous fish, however, were not the basis of subsistence in Mesolithic Scandinavia, suggesting non-migrating fish were behind the large dependency on aquatic resources. On the Canadian south-west coast, salmon[59] appear to have been fished at low intensities for millennia. In general, zooarchaeological analyses suggest that salmon did not become an important resource on coastal Salish and the west coast of Vancouver Island until about 500 years ago, the zooarchaeological record up to 5000 years ago showing low dietary importance prior to a dramatic increase from around 500 years ago (McKechnie, 2005; 2007; 2012; McMillan et al., 2008; Monks, 2006). The societies there appear instead to have been heavily reliant on herring, although both salmon and other fish species contributed to the dietary intake (McKechnie and Moss, 2016). It can be argued that these records do not

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[57] Although Early Holocene archaeological sites in eastern Baltic countries appear to be equally deprived of salmon bones, while bones from freshwater fish species are more abundantly occurring (Lõugas, 2017:Table 4.1).

[58] If appropriate locations connected to modern salmon rivers could be found and sediment cores could be extracted, sediment DNA would enlighten this matter further; see e.g. discussions in Thomsen and Willerslev (2015).

[59] On the west coast of North America and in Japan the primary salmon species are Pacific salmon belonging to the genus *Oncorhynchus*, while European salmon are Atlantic salmon of the genus *Salmo*. Differences between the two genera exist, but are not further discussed here.

directly indicate the degree of residential mobility or the level of complexity in societies prior to ethnographic studies[60]. However, the archaeological record, apart from differences in fish species abundance, does not indicate major changes. In certain contexts from south-western Vancouver Island, e.g. at the Huu7ii Big House and Back Terrace of Huu-ay-aht territory, the fish bone frequency seems to have been larger in the oldest contexts. Even though the oldest contexts have a lower species abundance and the younger contexts have more obvious year-round occupation, seasonality indicators (sedimentation in the shell midden) still indicate their presence throughout the year during the oldest occupation phases (McKechnie, 2012), albeit with intensified use during the herring fishing season.

Further to the north, on the northern Canadian coastline and on the coastline of Alaska, salmon appear to have occurred more frequently, often dominating the bone assemblages (McKechnie and Moss, 2016), although temporal resolution is often unavailable for the northernmost sites, for now rendering interpretation concerning early salmon exploitation impossible. Some studies of Alaskan archaeological sites indicate early salmon use, but they also highlight freshwater fishing and hunting of terrestrial mammals (Choy et al., 2016). Other studies highlight a large temporal variation when assessing the abundance of salmon during the last 2200 years at well-known Alaskan spawning grounds (Finney et al., 2002). The point being made is twofold: first, salmon runs appear to vary in density at a millennial scale, and second, the extraction of fish other than salmon should be acknowledged as highly important, even in areas where historical accounts of high salmon dependency have been documented. Coincidentally, freshwater fish also aggregate for spawning activities. This is especially true for cyprinids (e.g. roach) living in slightly brackish waters (as during the initial Littorina phase in the Baltic Sea), as they require/prefer non-saline influenced freshwater to spawn, even though they can live in slightly brackish water systems; thus they travel upstream into rivers and lakes to spawn (Kullander et al., 2012). The ability to capitalize on these aggregations would generate similar conditions as capitalizing on annual salmon runs: generating resource variability and resource predictability in the landscape, identified as particularly important to the development of complexity among foragers (Rowley-Conwy and Piper, 2016).

8.3.2. The importance of freshwater fish

Seventy years ago Clark argued that the Early Mesolithic societies in northern Europe developed large-scale fisheries (Clark, 1948:58), by discussing finds of

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[60] In other words, these sources do not tell us whether complex behaviour started with the salmon runs or if they were present in the societies prior to 500 years ago and thus prior to the increase in salmon frequencies in the bone assemblages.

pike bones, which had some decades earlier been found in the Danish bogs, and by relating them to finds of fish hooks, bone leisters and fishing nets. Thirty years later, and in line with the idea of a strong aquatic dependency among Mesolithic foragers, Stig Welinder argued for a large bioproductivity in nutrient-rich lakes (Welinder, 1978). By demonstrating a temporal and spatial framework, albeit with a low frequency of data, Welinder argued for the expansion of the Early Mesolithic Maglemose culture following nutrient-enriched lakes, which he suggested originated on the British islands and then encompassed Denmark and Scania and expanded further north. However, his model is somewhat simplistic and the evidence he offers are often ambiguous. For example, a temporal increase in healed injuries seen in terrestrial game is argued to indicate population intensification and a more stationary lifestyle, as the same animal was hunted twice, but the evidence presented is based on a small data set and without full consideration of taphonomic biases (Welinder, 1978). Furthermore, the increase in naturally occurring fish bones in certain stages of the sedimentation of the slightly brackish freshwater lagoon Spjälkö, used as an analogy, might be caused by occasional lack of oxygen (Liljegren, 1982), as is typical in eutrophic lakes (Degerman et al., 2002) and unrelated to human exploitation. Moreover, Welinder's examples of human occupation at the Spjälkö lagoon are not based on Early Mesolithic finds, but on much later human societies utilizing the eutrophic lagoon. However, despite this, there is merit to his suggestions.

When studying different types of modern lakes, it is apparent that hypertrophic lakes, i.e. lakes in a state of eutrophication, are exceedingly bioproductive and hold almost twice as much fish compared with other types of freshwater lake, mainly with an abundance of cyprinids (Degerman et al., 2002:127). However, even if lakes with ongoing eutrophication can harbour a large biomass, other freshwater systems are equally important, especially during spawning periods, when rivers and streams leading to spawning lakes become densely packed with fish. In addition, while Mesolithic inland settlements are often located near a shallow lake, they are also often situated close to an outlet to a larger water body. These types of location, close to rivers and streams, have often been discussed in terms of transport and communication (Haughey, 2012; Larsson, 1982; Sulgostowska, 2006). However, when considering a freshwater fish-dependent subsistence base, alternative interpretations can be made. The large bioproductivity of shallow lakes can be exploited all year round, while the outlet to larger water bodies enables exploitation of the seasonal movement of different freshwater fish as they congregate for spawning activities. These spawning or aggregation activities occur at slightly different periods for different species, and even twice a year for some (e.g. roach), and enable multiple mass catch opportunities, if exploited at optimal times and if storage options were available. Therefore freshwater fish can be available all year and it is, to a certain degree, the application of the right fishing technique during the different seasons that determines the amount of fish that can be extracted (Bērziņš, 2010).

The importance of Early Holocene freshwater systems is further exemplified on Gotland, where the Early and Middle Mesolithic period sustained what appears to have been a steady human population, whereas during the Late Mesolithic the population seems to have declined, with only sporadic and probably not sedentary visits. This is indicated by the continuity of radiocarbon dates in the two earlier time periods and a large hiatus of radiocarbon dates from the Late Mesolithic period on Gotland (Apel et al., 2017). Considering the evidence presented in paper V, freshwater systems could have been the reason why people ventured onto Gotland and continued a familiar way of life, strengthening the arguments of an Early Mesolithic freshwater-dependent economy as well as suggesting growing mainland populations 'pushing' people into new areas that still had available and unclaimed resource hot-spots. The evidence from Gotland provides interesting analogies with the variability of Scandinavian Mesolithic foragers, as here, compared with mainland Sweden, they may not have adapted to a marine lifestyle when the lakes became completely overgrown (and had lost much of their bioproductivity), but rather moved away from Gotland to new areas, and so left a hiatus in the archaeological record. The reason for the population decrease on Gotland might also be related to the Littorina transgression, which flooded many Gotlandic freshwater lakes with saline water and caused a collapse of the freshwater-dependent aquatic fauna[61]. This differs from the Scandinavian mainland, where people were still able to use freshwater systems if they wanted, seen, e.g., with the high frequency of freshwater fish bones from Skateholm (Jonsson, 1986; 1988). But they could also choose not to, as indicated by the ichthyo-archaeological material from Tågerup and Segebro (Eriksson and Magnell, 2001; Lepiksaar, 1982).

8.4. Resource hot-spots, population density and mobility

The implication for Early Mesolithic Scandinavia is that a pre-disposition towards terrestrial animals, aquatic mammals or diadromous fish is ill advised; given the zooarchaeological record, other resources could be more important for subsistence and could also be caught in large enough quantities to generate the surplus needed for a sedentary lifestyle. Freshwater fish fulfil the need in terms of sustaining large

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[61] Suggesting lower bioproductivity on Gotland; this, in turn, led to an environment that could not support a large group of stationary foragers. It is therefore possible that Gotland became gradually depopulated, if population density is correlated with food resource density abundance (Birdsell, 1968), as people moved away from the island. These inferences imply an adaptation to changing environmental prerequisites by increasing mobility, because dependence on aquatic resources is, under certain circumstances, considered a density-dependent response (Binford, 2001:385), suggesting that when aquatic resource abundance diminished, mobility (which on an island implies abandonment) would be an available option.

numbers of people and can also be considered important in later contexts, such as at the Late Mesolithic site of Skateholm in southern Sweden, where freshwater fish is the most abundantly occurring type of fish, even though the site is located in a lagoon next to the Baltic Sea (Jonsson, 1986; 1988) that was brackish-marine at the time of occupation (Emeis et al., 2003; Gustafsson and Westman, 2002). Furthermore, when considering the more than 1000-year halt in Neolithic expansion as Neolithization reached northern Europe (Cummings et al., 2014:17; Rowley-Conwy, 2014), i.e. the Baltic Sea region, a long tradition in aquatic resource exploitation makes sense as an explanation of the observed pattern[62]. If the foraging societies in Scandinavia were experiencing high population densities by the end of the Mesolithic period, because of the surplus available in the aquatic system, and if a long and strong tradition of aquatic resource exploitation[63] had led to a continuous increase in population density and larger group sizes, as suggested by the larger population densities and group sizes commonly observed among ethnographic aquatically dependent foragers (Binford, 2001; Kelly, 2013; Marlowe, 2005), then it is plausible that high population densities could have led to increasing territoriality. Ethnographic analogies suggest that if one group of people gains advantages by using fish to reduce mobility, they would be able to support a larger population and outcompete smaller groups of mobile people (Kelly, 2013:107). Therefore, it stands to reason that mobile groups who live in the same area would be forced to reduce their residential mobility and adapt to a fish-based diet, otherwise they would constantly and forcefully be removed from favourable nutrition extraction points in the landscape, which would increase their living cost, or attract territorial displays of violence from the more fish-reliant (and correspondingly more numerous and territorial) societies.

Resource exploitation ‘hot-spots’ would, under these circumstances, be highly valuable (Nilsson et al., 2018) and if they were extensively exploited, it may imply that the landscape would eventually become crowded, in the sense that mobile foraging strategies and an egalitarian lifestyle would not be able to compete with large sedentary communities who controlled the most favourable aquatic ‘extraction’ zones. Consequently, and if considering the halt in the Neolithic expansion, it may be conceivable that the Mesolithic north European societies had,

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[62] The importance of aquatic resources fits the archaeological evidence, such that a colonization by Neolithic farmers or adaptation to a Neolithic lifestyle is, on this basis and on initial contact (hence the more than thousand-year halt in the Neolithic expansion), not conceivable. This is particularly the case considering that the technology of Neolithic farmers was not superior to the technology available to Scandinavian foragers, as, e.g., when French, British and Russian explorers subjugated the complex societies of the north-west coast of America in the 18th century. Therefore, if the Scandinavian foragers had little to gain from adapting to farming (cf. Rowley-Conwy, 2014), i.e. the aquatically dependent foraging lifestyle held more advantages than disadvantages compared with the initial Neolithic lifestyle, a halt in the expanding Neolithization is reasonable.

[63] From at least the Early Mesolithic period onwards.

through millennia of population increase, facilitated by a high, but often both temporally and spatially varied, bioproductivity of the aquatic systems and a knowledge of how to use it in an optimal way, established a way of life that was in many ways similar to the early agrarian societies.

High population densities have been suggested on the west coast of Sweden based on a large number of Early Mesolithic sites[64] (Schmitt et al., 2006). These suggestions are strengthened by the results in paper IV, where a high population density is suggested to have contributed to an overexploitation of marine mammals. The initial pioneer subsistence strategies on the west coast of Scandinavia appear to have been focused on the hunting of marine mammals, as observed by large numbers of marine mammal bones in the zooarchaeological assemblage from the oldest phase of Huseby Klev. This initial high abundance of marine mammals was eventually followed by a possible population decline, which is indicated by low frequencies of both seal and dolphin bones in later occupation phases and an apparent increasing dependency on marine fish. The increasing temporal fish dependency is supported by increasing numbers of fish bones in the zooarchaeological assemblage from Huseby Klev[65]. Changes in subsistence strategies are also shown by a general chronological shift in the location of the Swedish west-coast settlements, from being situated in narrow straits during the Pre-Boreal chronozone, to being located within bays in the Boreal and Atlantic periods (Kindgren, 1995). This change in location of the settlements (Fig. 7 lower) supports the interpretation of a temporal increase in fish dietary importance corresponding to a marine mammal decrease. In addition, a higher reliance on fish compared with marine mammals should also be expected as the once elevated bioproductivity in the ocean declined, as the Scandinavian ice sheet melt water no longer washed terrestrial nutrients into the marine waters of the Swedish west coast. This process would have gradually ceased during the Pre-Boreal chronozone. Around 11,000 cal. BP, the ice edge would have been situated around mid-Värmland in south central Sweden, efficiently washing land-locked nutrients into the Skagerrak ocean, as melt water was freed from the melting ice sheet[66]. A thousand years later (~10,000 cal. BP) the ice edge zone would have moved up to Jämtland, with a narrow ice tongue reaching down to Härjedalen, and the melt water would no longer reach Skagerrak (Fig. 23).

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[64] Schmitt et al.'s (2006) estimations suggest 10,000 sites from central Bohuslän during a 1000-year period at the onset of Holocene.

[65] However, because of unequal efforts to fine-mesh sieve soil samples from the oldest occupation phase and because of variations in the taphonomic history of the different assemblages, the actual number of recovered fish bones between the individual phases might be somewhat difficult to compare (see also footnote 44).

[66] This would have enabled the accumulation of the large shell deposits observed in the area (Fredén, 1986; 1988).

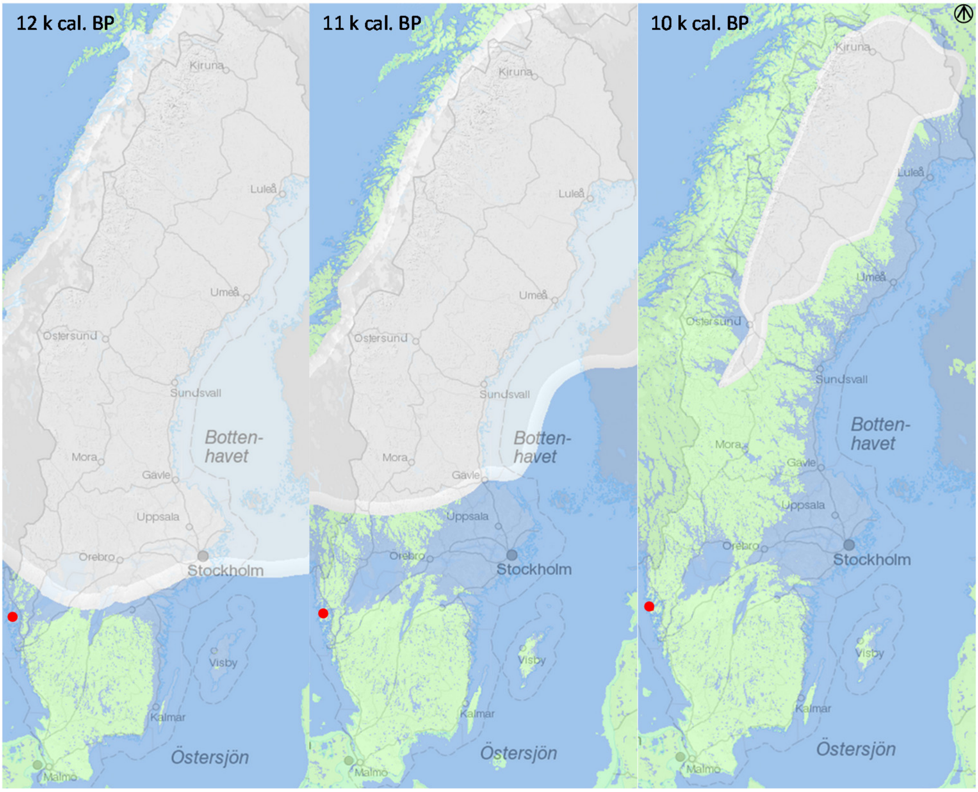

Figure 23 Shoreline displacement map showing the extension of the Swedish ice sheet around 12,000 11,000 and 10,000 cal. BP. Red dots indicate the location of Huseby Klev. Maps generated from SGU.

Along with the retreating ice sheet the prerequisites for an abundance of local top predators ceased, which, in combination with a large human population still hunting aquatic mammals, possibly led to a local decline in the marine mammal population[67].

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[67] It should be noted that the temporal increase in fish dependency is visible, but not obvious, in the modelled diet of the inhabitants of Huseby Klev (although the collapse of marine mammals is), as presented in paper VI. This is mainly caused by the prior information applied to the analysis, where average ethnographic data at corresponding latitudes is used. Because of the unique circumstances associated with ice edge-melting zones, where large amounts of melt water add terrestrial nutrients to the ocean, there might in fact not be any clear ethnographic analogies for humans living in this type of environment, i.e. on the Scandinavian west coast during and prior to the Pre-Boreal chronozone (which in Huseby Klev is represented by the PBO–EBO period). As such, the model used in paper VI might be missing the target; it might be more appropriate to, in the future, construct different types of frameworks when modelling pioneer subsistence in unique environments with no modern parallels.

Large population densities on the west coast, and possibly all of southern Scandinavia, may also be implied by evidence of recent genome sequence data, indicating a greater genetic diversity among Scandinavian Mesolithic foragers, compared to contemporaneous foragers from southern and central Europe (Günther et al., 2018). The Scandinavian genetic diversity has been interpreted as an indication of genetic mixing of two different populations migrating from separate directions, via a north-eastern coastal route and from the European continent via Denmark, into Scandinavia to meet and mix (Günther et al., 2018; Mittnik et al., 2018). Given the optimal marine conditions, i.e. an ecological bonanza in the ocean along the Scandinavian west coast during initial Holocene, see discussions in paper IV, a greater human genetic diversity might also indicate high population densities here. This in turn could imply that the observed migration was in a sense 'driven' by an aquatic abundance[68], which, once encountered, provided optimal conditions for staying here, resulting in higher population densities in Scandinavia if compared to more southern regions of Europe during the Early Holocene.

A large population density could also be plausible at Norje Sunnansund, where the calculations of taphonomic losses, as presented in paper III for the large amount of fish bones found at the site, indicate catches of fish large enough to support a large population over a long period[69]. Furthermore, these types of large fish catches were not unique for Norje Sunnansund, e.g. as illustrated by the contemporaneous fish traps found at Haväng (Hansson et al., 2018; Nilsson et al., 2018), which were large and located in areas where they could provide large catches of fish. Because of the fishing capacity of the fishing weirs at Haväng, its location within 1–2 days travelling from Norje Sunnansund (about 60 km by boat) and because most coastal sites from the Early Mesolithic period are now submerged and evidence of them

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[68] The aquatic abundance on the west coast and the abundance created by eutrophic freshwater lakes connected, via a river or a stream, to the slightly brackish Baltic Sea (see discussion in Chapter 8.3.2.)

[69] These estimations can be further enhanced by considering that edible plants and mammals were not included in the calculations, even though, as suggested in paper VI, protein from these sources combined amounted to almost 50% of the dietary intake at Norje Sunnansund. Therefore, these dietary sources have also been subjected to a taphonomic loss and would likewise, if similar taphonomic loss scenarios had been presented for these subsistence categories, indicate much larger quantities of originally hunted animals and gathered plants than is visible in the recovered archaeological assemblage. While it is difficult to compare the taphonomic loss between different dietary source categories, one way to cope with these difficulties is to use the estimated source-specific proportions of protein subsistence from paper VI. If these dietary signals are reversed, they could function as a link between variations in taphonomic loss between different dietary sources and the recovered bone assemblages on different sites. However, the differences in accumulation time must be accounted for, i.e. the protein in collagen is an accumulation from the diet from the last approximately 10 years, while a bone assemblage can have accumulated over much longer time spans (or shorter), so the link should be taken as an indication and not taken literally.

are, consequently, difficult to obtain, the results from Haväng and Norje Sunnansund could imply a general population intensification on the east coast of Sweden. In other words, the results from Haväng and Norje Sunnansund suggest, because of the immense difficulties in recovering Early Mesolithic sites (especially with organic preservation), that it is possible that all similar environments on the east coast have the same prerequisites for generating large amounts of fish that could sustain a large population[70]. Therefore, the data from Norje Sunnansund can be used inductively to make inferences about other societies living in the same landscape. Ethnographic analogies suggest a correlation between the proportion of fish in the diet and reduced residential mobility (see Marlowe, 2005:Fig. 6). By following these arguments, it could be suggested that Norje Sunnansund should not be considered an atypical occurrence, and even if it was 'the first' sedentary community (which of course it was not), other neighbouring societies and groups of people would start to follow in its footsteps[71].

8.5. Settlement size

The size and extent of an archaeological cultural layer or a settlement also affect how it is interpreted and, although it is notoriously difficult to map the extent of a Mesolithic settlement, because of the large time span involved (and the many taphonomic agents that have affected the material since the time of occupation), some observations and comparisons can be made. When studying settlement size, it appears that the Norje Sunnansund site is roughly three times the size of the individual sites from Skateholm, i.e. the estimated original settlement size was around 6000 m^2 at Norje Sunnansund (Kjällquist et al., 2016:85), compared with a suggested 1500–2000 m^2 for Skateholm I and Skateholm II each (Mithen, 1990:167). However, these estimations are probably based on the lower boundaries of the original settlements, i.e. Skateholm I and II were probably larger than 2000 m^2 each (Larsson pers. comm.). Furthermore, most of the other Skateholm sites (IV, VI, VIII) are heavily eroded or not fully examined, e.g. Skateholm IX, although they are considered to be of similar size as Skateholm I and II (Larsson pers. comm.). Norje Sunnansund is, consequently, smaller than the combined Skateholm sites (but the difference does not appear to be remarkable).

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[70] Implying that it is conceivable that all similar river/lake systems along the coastline were heavily exploited.

[71] Although consideration has to be given to the large variability among contemporaneous foragers (Rowley-Conwy & Piper, 2016) and the possibility that changes in climate, environment, available resources, demography, culture or social organization, etc., can disrupt a sedentary lifestyle and result in increasing mobility rates.

Skateholm is also a site at which territorial displays related to forager complexity have been highlighted (Layton and Rowley-Conwy, 2013). However, the settlement size estimates from Mesolithic sites are subjected to large biases, e.g. at Norje Sunnansund the size estimates are derived from the recovery of lithic finds in the topsoil and do not show how intensely the different parts of the area were used. Furthermore, because of the long period of time that has lapsed since the period of settlement use, much information has been lost through different transgressions and soil erosion, etc. In addition, no temporal resolution is available from the unexcavated parts of Norje Sunnansund, and the parts that have been excavated and dated show a large time span[72] such that the estimated settlement size should be considered with much caution. Also, the very concept of settlement is problematic because it is debatable what a settlement actually is. For example, a settlement is often considered to be the site that is currently being investigated, while to the original occupants the site might just have been part of the settlement, i.e. the house where you sleep does not have to be at the same location as where you deploy your fishing traps or process your food[73]. The argument of settlements covering large areas is also strengthened by ethnographic accounts, as, e.g., of the Evenks, whose settlements are often significantly larger than the areas normally considered in discussions of archaeological forager settlements (Grøn and Kuznetsov, 2000), depending on how a settlement is defined and what is considered to be part of it[74].

Nevertheless, the size of the Norje Sunnansund settlement is large, and thus in many ways comparable with both the different settlements at Skateholm and the largest Late Mesolithic settlements in Denmark, cf. e.g. Rowley-Conwy

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[72] Which is enhanced by bad preservation of carbon in the bone collagen and a contemporaneous ^{14}C calibration plateau leading to an even larger time frame for site occupation.

[73] Considering the smell of, e.g., fermenting fish, it might also be considered unlikely that the living houses/huts were located in the vicinity of the fermenting products. This is further highlighted by ethnographic accounts concerning fish fermentation, such as: 'Lukten från ett sådant fiskförråd kan man känna på en dryg kvartsmils avstånd' [The smell from one of the fermentation pits can be felt from miles away] (author's own translation) (Waxell, 1953:138) and 'it is impossible to breath from the heavy odor of the decayed fish' (Jochelson, Unpublished typescript of MS), suggesting that the smell was indeed great and could very well have limited residency in direct relation to the fermentation pits (see also footnote 11 in Definitions, Chapter 3.1.1).

[74] This is exemplified in the discussions of Ole Grøn and Oleg Kuznetsov, concerning an Evenk settlement, who state that: 'One must be aware that a settlement is more than a central area with one or more dwellings. Around the dwellings will be different types of platforms, storage pits, storage areas, shades for humans and animals, activity areas, outdoor hearths etc. Around the structures belonging to the central living area will normally be a zone with a heavy impact on the vegetation from traffic, toilet activities, collection of firewood, bark for roofing etc. This can also be regarded as a part of the settlement as far as it is a zone where daily and regular activities are carried out' (Grøn and Kuznetsov, 2000:219). If the above-mentioned parts of a settlement are included in its definition, Evenk settlements can cover 600×500 m up to 1000×500 m (Grøn and Kuznetsov, 2000).

(1983:Table 10.3.). However, even if Norje Sunnansund is considered large, it is still not as large as some the biggest contemporaneous settlements, such as Sværdborg I, Lyngby I and II, which have been estimated to cover around 15,000 m^2 each (Blankholm, 2008:119).

8.5.1. Home is where I dwell?

When discussing territoriality and sedentism, the actual dwellings of a society become important to consider. Indeed, dwelling structures (houses/huts) have been found from both the Early Mesolithic, e.g. in Ulkestrup Lyng on Zealand in Denmark (Andersen et al., 1982), Årup in north-eastern Scania in Sweden (Nilsson and Hanlon, 2006), Ålyst on Bornholm in Denmark (Casati and Sørensen, 2012) and in Duvensee in Germany (Bokelmann, 1986), and Middle Mesolithic, e.g. Lussabacken Norr in Blekinge, south-eastern Sweden (Björk et al., 2016), Ljungaviken, also in Blekinge (Kjällquist and Friman, 2017), Rönneholms bog in central Scania in southern Sweden (Sjöström, 2004), Saxtorp in western Scania (Larsson, 1975) and Timmerås in Bohuslän, western Sweden (Hernek, 1998). However, they are rare[75] and, even though the spatial distribution of flint debris has been shown to illustrate plausible dwelling structures (Björk et al., 2015), our knowledge of Early and Middle Mesolithic living areas are limited.

In the early 1990s Binford points out the inverse relationship between mobility and investment in housing (Binford, 1990). In light of this it could, in some respects, be considered that a low abundance of known dwelling structures, from certain time periods, indicates higher mobility rates. This, however, does not have to be the case, which is touched upon by Bo Knarrström and Per Karsten concerning the lack of dwellings during the Middle Mesolithic phase of Tågerup, who, because of the good preservation at the site, argue that ‘they [the dwelling structures] seem to have been constructed in a way that left no direct traces’ (Karsten and Knarrström, 2003:37). This is further highlighted by Grøn, who stresses that even heavy dwelling structures ‘may leave a few post- or stake-holes not necessarily located along its outline, or no subterranean traces at all … Therefore the absence of traces of a superstructure does not prove that there was none’ (Grøn, 2003:688). Grøn also compiled estimates of the sizes of known dwelling structures throughout the Mesolithic and Neolithic period and concluded

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[75] This is also likely related to the excavation techniques applied at many of the early excavations of Early and Middle Mesolithic sites, which often involved opening up only small areas or trenches. With modern excavation techniques, knowing what to look for and the use of machines, it is possible to open larger areas and clean large surfaces, so it is easier to detect postholes. Consider, e.g., that a minimum of six huts was found during the 2016 excavation of the Middle Mesolithic site Ljungaviken (Kjällquist and Friman, 2017), and that 10 Late Mesolithic post-built dwellings were located at the Strandvägen settlement in Motala (Molin et al., 2017).

that within the Early Mesolithic period dwellings increased in size and correspondingly 'The changes in household size starts well before the climatic changes of the Atlantic Transgression which altered what remained of the Pre-Boreal and Boreal plains' (Grøn, 2003:704). Furthermore, when studying the layout of some of the most well-known Early Mesolithic dwelling structures, Grøn determined them to have been of rectangular shape (Grøn, 1983), which is also obvious in the dwelling structures from Ulkestrup Lyng (Andersen et al., 1982), Holmegaard (Becker, 1945), Årup (Nilsson and Hanlon, 2006:126) and Ålyst (Casati and Sørensen, 2012), and indeed suggested for Early Mesolithic Maglemosian sites in general (Blankholm, 1994). Interestingly, according to Binford's collected ethnographic data, rectangular-shaped dwelling structures are significantly more common among sedentary (80.9%) than among mobile (16.1%) foragers (Binford, 1990:Table 1). While this by itself might seem like an insignificant observation, it might be important if it is also related to increasing dwelling sizes during the Early Mesolithic period. Furthermore, if both of these observations are related to an increasing dependency on fish it strengthens the argument for a decreasing mobility in Scandinavia starting in the Early Mesolithic period. Because the Scandinavian Early Mesolithic dwellings have mainly been found on inland summer seasonal locations, they might imply seasonal returns to the same location during the summer forays, i.e. the dwelling structures were possibly built as more 'permanent' buildings, even though the inhabitants themselves were absent for most of the year. Although difficult to prove and in need of further study, this might imply some level of territorial thinking. If the inland settlement sites were used repeatedly for many years in a row, it could also explain why some of the Early Mesolithic inland settlements, e.g. Ageröd, Lyngby, Holmegaard, Sværdborg, etc., are both large and include large assemblages of both lithic and organic remains, while only displaying summer seasonal indicators.

8.5.1.1. The absence of ceramics

Even though an important piece of the Mesolithic puzzle has been revealed with the demonstration of a means to store large quantities of food, the absence of ceramics makes it difficult to study other methods of storage or to show evidence of storage at a broader scale. Ceramics are very important when discussing storage among agriculture-practising societies (Cunningham, 2011). The absence of ceramics is in itself often discussed as a sign of mobility, because ceramics are difficult to transport as a result of their brittle nature and thus not easily used by mobile foragers. Furthermore, stationary foragers could arguably have made good use of ceramic vessels in a similar manner to agricultural societies. However, even though these points are noteworthy, they are not by themselves arguments for the absence of sedentism. Ceramics could easily not have been invented or introduced into an area, and cultural traditions and practices might have utilized more perishable materials in the same way, thus lessening the need for ceramic vessels and again highlighting a possible increase in a taphonomically induced absence of complexity signals. Furthermore, while most of the ethnographic foraging groups on the north-west coast of America used ceramics, some did not, e.g. the Aleuts (Lantis, 1984), suggesting that it is possible to have complex societies, with limited residential mobility, without the use of pottery.

8.6. The emergence of territoriality

With the evidence of a large dependency on aquatic resources, substantial settlement sizes and the ability to store food during the Early Mesolithic period, continuous population intensification can also be argued for. This could eventually lead to crowding, which, in turn, could lead to increasing societal stratigraphy and growing levels of complexity, which fits with Binford's observation that 'elite control of resource location in this instance is heavily biased in favour of aquatically dependent peoples' (Binford, 2001:426). In other words, aquatically dependent groups are more likely to practise territorial control, especially when resources are both temporally and spatially reliant but infrequently occurring (Rowley-Conwy and Piper, 2016). In this type of setting, social stratification is conceivable and leaders could, under such circumstances, be able to assert varying degrees of command and direction on their subjugates[76]. In fact, an expanding territoriality may be illustrated during the Mesolithic period, i.e. over time, and, as presented in paper VI, the evidence indicate a general pattern that started to appear in southern Scandinavia. Subsistence strategies were homogenized and the overall isotope niche width decreased[77], which is illustrated by a temporal homogenization

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[76] It should be noted that this need not always be the case. For example, among the Sami societies in northern Scandinavia a high dependency on fish in the 17th century was connected with poverty, whereas status and wealth were related to reindeer ownership (Fjellström, 1986), suggesting that a high dependency on fish does not automatically lead to large population densities and social stratification. It should also be said that the increase in Sami reindeer husbandry has been related to increasing demands for furs and skins by the Nordic states (Hedman 2003). The low status of fish was probably not based on the Sami's original foraging lifestyle, as it likely incorporated both fishing and hunting to a large degree (Bjørklund, 2013), but instead was a reflection of wealth generated through exchange with large neighbouring communities (see also footnote 54).

[77] Isotope niche width is not equivalent with diet breadth, as it is a reflection of the isotope values in a diet (which can vary for many reasons, see paper VI) and not the actual diet itself [see e.g. definition in Bearhop et al., (2004)]. A narrow isotope niche width implies, all else being equal, a specialist feeding behaviour whereas a wide isotope niche width implies a broader diet base. In general this means that: 'populations that consume a wide range of prey species will exhibit wider variation in their tissue isotopic signatures than those consuming a narrow range of prey items' (Bearhop et al., 2004). When applied to human isotope niche width, as done in paper VI, the narrower isotope niche width among Middle Mesolithic foragers, compared to Early Mesolithic foragers, suggest a more specialized diet among the former, i.e. a temporal specialization.

of human δ^{13}C and δ^{15}N collagen values (see paper VI). Indications of territorial behaviour is further strengthened by the lack of overlapping human isotope signals between marine and freshwater environmental context, i.e., as illustrated in paper VI, no human isotope values from marine environmental contexts overlapped with human values from freshwater environmental contexts during the Early Mesolithic period, and only one clear overlap was noted during the Middle Mesolithic period (and all, at the time of writing, available Early and Middle Mesolithic isotope values have been considered) (Fig. 24).

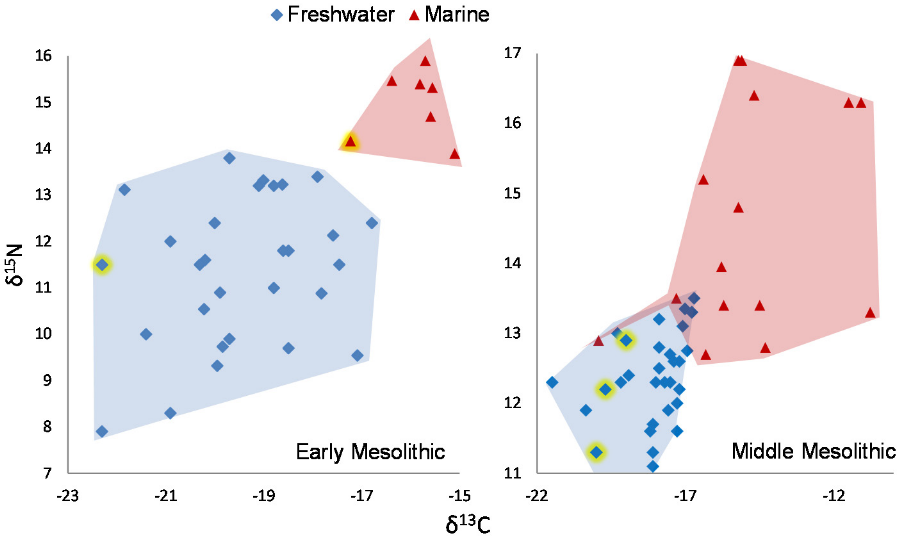

Figure 24 Bulk collagen stable isotope data from all available Early and Middle Mesolithic humans from Scandinavia showing no isotopic overlaps during the Early Mesolithic and little overlap during the Middle Mesolithic, which suggests limited coast–inland mobility. Yellow circles around data points indicate collagen from teeth; all other data points derive from bone collagen (see paper VI appendix for details).

Exchange and cultural influences did happen, as illustrated by the spread of new technologies (Bergsvik and David, 2015; Damlien et al., 2018; David and Kjällquist, 2018; Sørensen et al., 2013), the variation in human strontium isotope signals indicating different origins for the people found at Norje Sunnansund (Kjällquist and Price, Manuscript), and ancient DNA evidence of migration (Günther et al., 2018). However, it appears that people tended to stay put once they had moved into an area, indicating that there might have been social and cultural exchange of individuals (e.g. through marriage). This implies that, once the exchange had been made, people adapted and settled into the new area and seldom travelled between marine and freshwater environments (or seldom enough not to leave an imprint in their bone collagen, based on what they were eating).

The possibilities to investigate forager mobility by means of $\delta^{13}C$ and $\delta^{15}N$ stable isotope analysis have previously been addressed through, e.g., the Early Mesolithic Hanaskede man, who displays more marine isotope signals in his teeth, i.e. from his childhood when his teeth were formed, than in the bone collagen from his skull, reflecting his adult diet (Lidén et al., 2004) and through intra-individual differences in $\delta^{13}C$ and $\delta^{15}N$ values between dentine and bone collagen from the individuals from Mesolithic Motala (Günther et al., 2018:S1). The latter having been interpreted as a conformation of a high level of mobility among Scandinavian Mesolithic foragers in general (Günther et al., 2018:S1). However, it should be noted that these differences could be the result of logistical and not residential mobility. Due to a more limited development time for dentine (Moorrees et al., 1963), compared with bone remodelling rates (Kini and Nandeesh, 2012; Sims and Martin, 2014), seasonal or task specific forays, i.e. logistical mobility, impact the stable isotope signals in dentine more than bone[78], if the forays were made both during adolescence (when the dentine was formed) and as adults (when the bones were remodelled).

Considering Fig. 24, Early Holocene human mobility may have been more limited than has previously been considered, i.e. as suggested by a perceived high mobility rate during the Early Mesolithic period (Jensen, 2001). Furthermore, with a temporally increasing dependency on aquatic resources and a more sedentary lifestyle, territoriality could have increased. By the Middle Mesolithic period southern Scandinavia could have been divided into many different territories, each with its own group of people who, because of the limited amounts of available land, were highly reliant on aquatic resources. This could have led to territorial claims, which resulted in territorial displays such as observed in Middle Mesolithic Motala, with human impaled heads (Hallgren, 2011; Hallgren and Fornander, 2016). These impaled human skulls indicate a territorial link to the site, regardless of whether the humans displayed were local ancestors or foreign tribal war victims. Indeed, a similar practice could possibly be suggested at Norje Sunnansund, where an oak rod was found vertically inserted into the lake bottom, just outside the terrestrial layers, with a number of human skull fragments[79] in the lacustrine waste layer close to the rod (Fig. 25).

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[78] A more limited formation time would cause the diet during a seasonal absence, from a sedentary settlement, to make up a larger portion of the stable isotope values in the dentine collagen and 'external' diet sources would consequently influence the diet mixture responsible for the stable isotope signals in the collagen more in dentine compared with bone collagen.

[79] 16 calvaria fragments, 3 teeth and 1 phalanx, from at least two individuals, were found in the lacustrine deposits. Some of the cranial fragments could be refitted, even though found at some distance from each other, suggesting that they might have been intact skulls at the time of deposition.

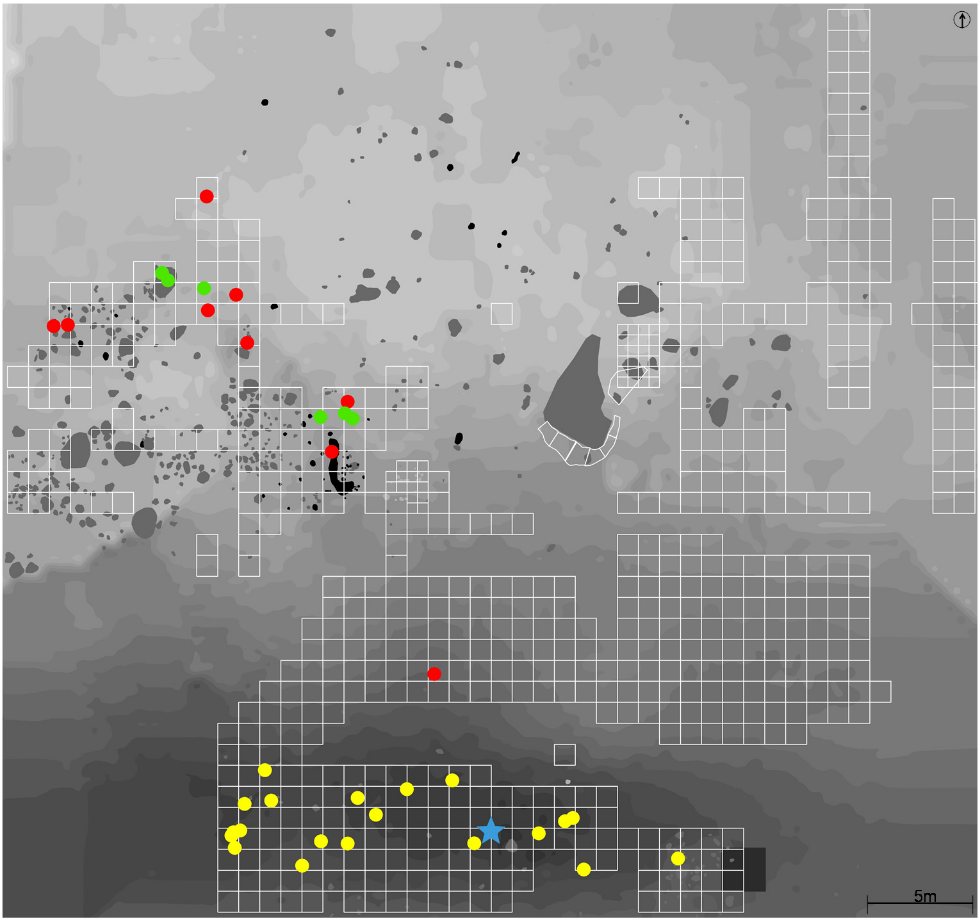

Figure 25 Human bones from Norje Sunnansund. Yellow dots indicate human bones in the lacustrine waste layer, green dots indicate human bones in the oldest terrestrial cultural layer and red dots indicate human bones in the youngest terrestrial cultural layer; the blue star indicates the location of the oak rod. Figure by Mathilda Kjällquist.

8.6.1. Territoriality through burial customs

The territoriality among Scandinavian foragers increased further over time and took new forms, such as territorial claims through ancestors, as indicated by the establishment of large, below-ground, cemeteries at visible locations, as seen in the Late Mesolithic period[80] (Grøn, 2015; Larsson, 1993). Territorial displays might also be seen during the Middle Mesolithic period, e.g. from Tågerup in

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[80] With the oldest burials from Skateholm chronologically located in the first centuries of the Late Mesolithic Ertebølle culture (Larsson, 1989).

western Scania, southern Sweden, where at least six graves were found, five of which were located within a limited area (Ahlström, 2001; Kjällquist, 2001) on an elevated hillock close to the settlement (Karsten and Knarrström, 2003:74). These graves might not represent all that were originally there, as they were rather badly preserved, hard to find during the excavation and located close to the edge of the excavation boundary, suggesting that some of the original burials might have disappeared and more burials might be located outside the excavation perimeters. Graves on highly visible locations can also be seen in Mesolithic Motala, where a number of graves were found adjacent to the river Motala Stream at Strandvägen (Gummesson and Molin, 2016).

A lack of cemeteries from Early Mesolithic Scandinavia might, as the most obvious explanation, indicate a lack of territorial displays by claims of ancestry. However, it might also reflect a taphonomic loss rather than an actual absence of cemeteries at the time. It is plausible that the burial customs themselves had gone through a temporal change, i.e. that during the Early Mesolithic period burials might have been displayed above-ground, as, e.g., among the Evenks, who commonly place their deceased clan members ‘in trees and on platforms in highly visible locations along the central travel corridors’ (Grøn, 2015:239). Such burials would not have been covered by sedimentation and do not have similar preservation prerequisites as below-ground burials. Furthermore, this type of above-ground burial could very well be the reason why most Mesolithic sites have ‘random’ human bones scattered among the ‘normal’ settlement waste, as has been observed on numerous occasions (Ahlström, 2001; Boethius, 2016a; 2018a; Brinch Petersen, 2016; Larsson et al., 1981; Newell et al., 1979; Schulting, 2015; Sjögren and Ahlström, 2016; Sørensen, 2016a). If this type of elevated excarnation system was implemented, it suggests that eventually the bodies and the platform structures on which the bodies might have been placed would decompose (Fig. 26 left), and some of the human bones would become incorporated among the normal settlement refuse. Incorporation into the cultural layers could happen either because the excarnations were located within the actual settlement area or, if they were located at a more visible spot[81] some distance away, e.g. around 50–100 m, from the central part of the settlement (as in the case of the Tågerup graves), through movement by dogs and/or children, or by adults, ‘collecting’ bones from the now decomposed and disarticulated remains.

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[81] As e.g. among the Evenks (Grøn, 2015), see fig. 26 right.

Figure 26 Two different Evenk excarnations. Note the scattered human remains underneath the collapsed and decomposing platform (left) and the highly visible location of the excarnation (right), which act as a territorial claim to the land. Photo: Ole Grøn. Pictures originally in Grøn and Grøn et al. (2015; 2008). Reproduced with the authors' permission.

Other explanations for human bones being present in cultural layers at Mesolithic sites are plausible, such as ancestral cults having human bones on 'display' and re-excavation of known graves to remove certain bone elements. Amy Gray Jones concludes in her thesis that 'the disarticulation and manipulation of human remains, as a significant element in Mesolithic mortuary practices, can no longer be ignored' (Gray Jones, 2011:207), but she also acknowledges a large variability in Mesolithic treatment of body manipulation practices. The explanation of active human manipulation of human skeletal remains, however, neither strengthens nor refutes territorial displays through ancestry, and the reason why manipulations occurred still eludes us. Other 'simple' explanations for human bones being present at Mesolithic sites include exposure by accidental digging up of older graves, digging by dogs or wild boars or because the bones have been washed out, by wave erosion, from burials. More complicated reasons for the presence of human bones at Mesolithic sites have also been suggested, such as the bones representing personal ornamentation, trophies, scalping, violence and cannibalism, or because human remains were carried along during moves through the landscape (Brinch Petersen, 2016). As much of the former coastline of the Early Mesolithic period is absent and, consequently, the settlements from those areas, it is also conceivable that the largest cemeteries were located in coastal areas, especially if they were used as territorial markers, which means that they will be very hard to find.

The cemetery at Oleniy Ostrov, located on an island in the Onega Lake in Karelia, western Russia, is dated to the Boreal chronozone (Price and Jacobs, 1990), with the oldest dates from the site being from around 9050–8680 cal. BP (Mannermaa et al., 2008). Oleniy Ostrov is therefore contemporaneous with the youngest phase of the Norje Sunnansund settlement and the Gotlandic sites of Gisslause, Stora förvar and Stora Bjärs, etc. This suggests that contemporaneous human groups did create cemeteries, even if not confirmed in Scandinavia[82], in areas with similar living conditions. Furthermore, because Late Mesolithic Scandinavian societies have been shown to create cemeteries, which have been linked to territorial displays, and, because human bones are frequently found in the cultural layers at Mesolithic sites, cemeteries could have been created in Early Mesolithic Scandinavian contexts as well, even if as elevated excarnations or located in (now submerged) coastal areas. Although difficult to prove, this in turn would imply territorial displays, which could be further interpreted as an indication that the few

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[82] Although the late Early Mesolithic double burial from Kambs Lummelunda (81:1), Gotland, is located on a visible hillock, around 250 m from a stream connecting the Baltic Sea, about 1.5 km away, with a shallow freshwater lake, about 250 m from the grave (cf. FMIS (Sweden's National Heritage Board's database for archaeological sites and monuments) terrain map and SGU shoreline displacement map). The area where the grave was found has not been thoroughly investigated, so additional graves may exist.

human burials found from the Early Mesolithic are of people who did not die close to their home, and so were buried where they died, under-ground, to avoid creating a territorial marker where it was not appropriate. Alternatively, they represent people who were buried under-ground for other reasons. It is possible, e.g., for foraging societies to practise more than one type of burial; among the Aleuts excarnation is only one of many different ways in which they traditionally 'buried' their deceased (Corbett et al., 2001:257), suggesting that the type of burial employed is related to characteristics of the deceased individual and/or his/her social status[83]. Different types of burial have been suggested for the Late Mesolithic period in Scandinavia; excarnations have been suggested to occur alongside below-ground burials, based on ethnographic analogies and scattered human remains in the cultural layers of Late Mesolithic sites (Grøn, 2015). This is supported by scattered human remains in the cultural layer of settlements where graves are also present, e.g. at Tågerup (Ahlström, 2001; Karsten and Knarrström, 2003) and Motala (Gummesson and Molin, 2016; Molin et al., 2017). Individual-based burials are indicated by both burnt and unburnt human bones appearing in graves, e.g. at Skateholm (Larsson, 1988a) and Vedbæk (Brinch Petersen, 2015). At both Skateholm and Vedbæk, burials in dug-out canoes have been encountered (Brinch Petersen, 2015; Larsson, 1988a), similar to the boat burial at Møllegabet (Grøn and Skaarup, 1991; Skaarup and Gron, 2004). This, in combination with the variation in how the human bodies were placed in the graves[84], supports an interpretation of choice, possibly individually based, in burial practice.

If excarnations commonly existed on or close by Mesolithic settlements, it could be possible to locate them by the presence of post holes. Although it is difficult to assign post holes confidently to excarnation practices, it can be implied if they are located on elevated topography or at visible locations, and if the post holes are positioned at relevant distances from each other, e.g. as seen by the poles supporting the Evenk excarnations (Fig. 26). Following the above arguments, post holes from excarnations can be suggested at Norje Sunnansund, where a group of five post holes, without apparent analogies in other types of structures[85], were found on the most elevated part of the excavated area (Fig. 27). In addition, two other groups of post holes, also with five post holes each and clustered in a similar shape, are found on somewhat lower grounds nearby and in the vicinity of the human bones recovered from the cultural layer (cf. fig. 25 and fig. 27).

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[83] Exemplified by honoured people and prominent whalers, etc., among the Aleuts, who were often mummified and placed in caves near the sea (Aigner and Veltre, 1976).

[84] Compare e.g. the position of the human remains from the graves at Skateholm (Larsson, 1988a), Vedbæk (Brinch Petersen, 2015), Motala (Gummesson and Molin, 2016), Stora Bjärs (Arwidsson, 1979), Barum (Wallebom, 2015), etc.

[85] Originally suggested as possible wind shelters, small huts or as misinterpreted negative stone imprints (stone holes) (Kjällquist et al., 2016:105).

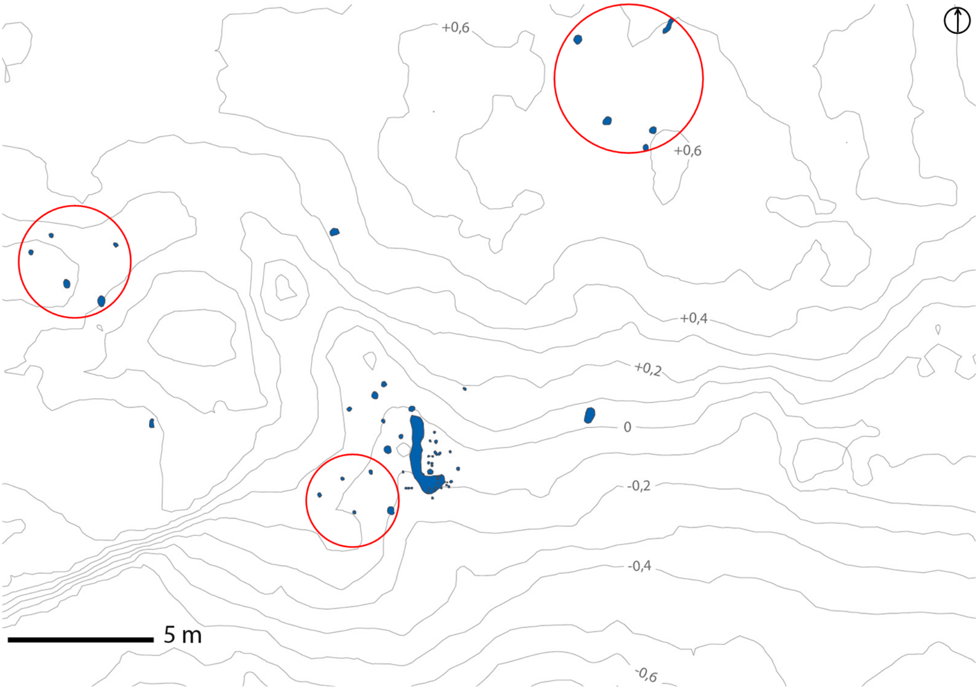

Figure 27 Three v-shaped groups of postholes, with five post holes each (circled in red), which might be related to excarnation practice. The northernmost (top) post hole group is located on the most elevated and visible ground at Norje Sunnansund. No cultural layer was preserved in this area. The two remaining groups of post holes are somewhat smaller and located on lower ground, where cultural layer was preserved, the human remains recovered from the terrestrial layers are found in their vicinity (cf. fig. 25). Original figure by Mathilda Kjällquist.

8.6.2. Territoriality through selective hunting

On the topic of temporally changing displays of territorial behaviour, indications of targeted hunting strategies, close to sedentary settlements, are demonstrated during the Early Mesolithic, as presented in paper II concerning Norje Sunnansund. Here it appears that fully grown animals from species with low reproduction rates were especially targeted in order to provide optimal raw materials for tools, clothes and weapon production. The same pattern has been observed elsewhere, e.g. in Early Mesolithic Denmark, where adult red deer appear to have been selectively targeted (Bay-Petersen, 1978). The age hunting profiles of red deer in Mesolithic Denmark have been interpreted as 'risk prone', with the aim of maximizing the return from each kill, suggesting that the enhanced risk of not catching prey was subordinate to the enhanced prestige of catching the *right* prey (Mithen, 1987)[86]. However, hunting strategies might not have functioned similarly in later periods, e.g. during the Late Mesolithic. This is suggested by comparing the hunting strategies for red deer seen in the zooarchaeological material from the Middle and Late Mesolithic phases at Tågerup (Eriksson and Magnell, 2001), although these differences need further investigation and more sites need to be compared, to be able to account fully for temporal trends. These indications follow the discussion in paper II, where a pattern of selective hunting strategies is only conceivable in non-crowded areas, i.e. when an area becomes crowded it becomes difficult to rely on the selective hunting of certain animal sizes and age groups because it will not be possible to 'control' the area. If this is related to territorial thinking, it would not be possible to control neighbouring areas between which the prey animals moved, and thus it would be difficult to prevent others from killing an animal before its optimal size had been reached, so the abandonment of selective hunting strategies is possible. However, what is perceived as selective hunting strategies could have other explanations. For example, the pattern observed could have been caused by ecological factors, with an increased taphonomic loss of certain species, such as better hunting grounds for young red deer being somewhat further away from camp compared with the best hunting grounds for wild boar[87]. If the raw materials from young red deer were deemed inferior in quality, i.e. compared with adult deer, this could have resulted in an increased schlepp effect of young red deer bones and, consequently, a perceived selective hunting. These arguments can only be strengthened or abandoned if more sites with preserved organic materials can be found and further studies made.

8.7. Adapting to thrive

The results, as interpreted here, suggests that subsistence strategies, sedentism and territoriality are not progressive, thus adding to the arguments of Rowley-Conwy (2014), who drew a similar conclusion. Sedentism and territoriality can evolve and devolve according to numerous unspecified rules and possibilities, environmental factors surely representing some, but where social dynamics, tribal warfare and technological advances, etc., are also co/parallel dependent factors. The Mesolithic time period should not be considered as something fixed and unchanging. Human cultures in general display a high variability, including foraging societies (Rowley-

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[86] This implies that the societies did not risk starvation if hunting failed, as mass catches of fish fit the demand for a risk-reducing subsistence strategy. This is also suggested by the practice of large-scale storage, e.g. through fish fermentation, which is traditionally seen as a risk-reducing strategy or as a way of coping with lack of predictability (Binford, 1980; Cashdan, 1983; Kelly, 1983).

[87] Because of variations in vegetation and/or topography, etc.

Conwy and Piper, 2016), especially if situated in a temporal and spatial context where the environment is changing constantly as a result of variations in climate, temperature, aquatic salinity, transgressions and regressions. By emphasizing the Early Holocene humans' adaptability to cope with changes, and by highlighting their means of enabling their chosen lifestyle, e.g. by implementing mass capture technology and having food preservation methods and storage capacity, improved hunting gear, selective hunting strategies, etc., a more complete spectra of foraging variability can be accounted for. Even though changes did occur, both environmentally and anthropologically induced, Early Holocene humans had the capacity to follow their own goals; they were able to thrive in the landscape and change their subsistence strategies according to their chosen way of life. The Early and Middle Mesolithic humans, much as humans today, sought niches in the environment where they could prosper. The archaeological evidence suggests that they were able to settle and live a sedentary lifestyle based on the abundance created by both marine and freshwater systems, and that they were able to cope with external perturbations by either adapting their subsistence strategies to available aquatic resources or by moving to other areas to continue their desired way of life.

9. Conclusion

In 1980 Larsson suggested a settlement system for the Middle Mesolithic period: the coast was perceived as providing winter occupation sites, while inland sites were used in the summer (Larsson, 1980). There is much merit to his suggestions; however, it is possible to take his arguments one step further. In this thesis it has been shown that Mesolithic humans exploited aquatic resources at a higher rate and from an earlier date than previously assumed. These foragers caught enough fish and practised preservation techniques that rendered them more resilient against external perturbations and enabled them to gather in large groups[88]. Although chronological and regional variations have to be considered, it can be argued that from the Early Mesolithic some foraging societies practised a delayed-return lifestyle, which allowed them to stay in agglomerated settlements that were probably located on the coast during the winter. Contrary to earlier beliefs, the social dynamics and mobility strategies did not necessarily have to encompass large movements of entire groups, because sedentism and all-year occupation could be an option for at least part of the population. This suggests that, from at least around 9500 cal. BP, people could have been able to live sedentarily at coastal locations, with a seasonal variation in population size as smaller groups took short foraging trips, e.g. inland during the summer and out to sea during the winter. While some people stayed behind at the permanent settlements, others left for hunting forays.

Over time, the evidence suggests the appearance of a general pattern in southern Scandinavia: subsistence strategies were homogenized, the overall isotope niche width decreased, people became increasingly reliant on fish (either by choice or because of diminishing numbers of available terrestrial fauna) and, consequently, increasingly territorial. The relatively large number of known Early Mesolithic sites (albeit without organic preservation) in the few areas where transgression has not submerged the landscape, e.g. on the coast of Bohuslän, western Sweden, suggests that areas with high aquatic bioproductivity probably became densely populated shortly after the ice sheet retracted. Given that basically all other coastal areas in Europe are now submerged, and considering that this thesis deals with all of the zooarchaeological remains from the few available Scandinavian Early Mesolithic coastal sites, the information from these investigations is of great importance for interpretations concerning the time period in question.

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[88] Although the ability to store food does not necessarily imply a sedentary life, cf. e.g. Ingold (1982; 1983). However, when seen in connection with other types of evidence, as presented here, it most likely indicates a larger population with a decreased residential mobility.

Furthermore, as previously known sites with preserved organic remains from Early Mesolithic southern Scandinavia have shown only summer seasonal indicators (Carter, 2001; Magnell, Submitted-b; Rowley-Conwy, 1993; 1999), the material presented in this thesis holds even more importance when studying Early Mesolithic subsistence strategies.

Nine areas of special interest can be highlighted. Following the discussions presented here, combining available evidence (presented both within the context of this thesis and elsewhere), there are now indications of: 1) Large scale storage through fermentation[89], i.e. the potential to preserve and store food for later consumption. 2) Mass catches of fish, i.e. large enough quantities of fish to feed a large human population for extended time periods. 3) Mass-harvesting technologies, i.e. fish weirs and traps located in favourable areas. 4) Freshwater fish dependency, i.e. large amounts of freshwater fish bones, a large human freshwater reservoir effect and freshwater fish isotope signals in the human diet. 5) Increasing marine fish dependency in marine environmental contexts, i.e., large number of marine fish bones, shift from marine mammal dependency to marine fish dependency, marine aquatic isotope signals. 6) A general homogenization of subsistence strategies and resource exploitation, i.e. a temporal diminishing of isotopic niche width. 7) Reduced residential mobility, i.e. year-round seasonality indicators, delayed-return subsistence strategies, lack of overlap between dietary isotope values from humans in marine and freshwater environmental contexts, size and appearance of dwelling structures. 8) Increasing population densities, i.e. possible over-exploitation of marine mammals, increasing fish dependency, greater human genetic diversity in Scandinavia, reduced mobility. 9) Increasing territoriality, i.e. selective hunting strategies, indications of excarnation practises as territorial markers.

Thereby, in conclusion, and if addressing the main question of the thesis, it has been shown that *fish were more important to Early and Middle Mesolithic human subsistence than has previously been conceived*. This, along with year-round seasonality indicators, mass catches of fish, mass catching equipment, the means to store large quantities of food etc., indicates that mobility was not the only risk-reducing subsistence strategy available. This has further implications, i.e. *it indicates*, following the discussion presented here, *an increasing territoriality and a growing societal complexity among the Early Holocene foragers in southern Scandinavia.*

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[89] Even though it is currently unknown how widespread the knowledge of fermentation was, the indications presented here could create a ripple effect: archaeologists dealing with foraging societies in northern latitudes are now better equipped to find signals of fermentation.

9.1. Abductive disclosure

In all areas of archaeology, we will never find the first or the earliest of anything, merely the first or the earliest *evidence* of something. In the case of the Early Holocene, our prior knowledge is, in addition, heavily biased because of the lack of coastal areas, extremely low frequencies of sites with preserved organic remains and no prior evidence of winter seasonal settlements during the Early Mesolithic. However, given the evidence presented in this thesis, it is now possible to better understand the Early and Middle Mesolithic periods in southern Scandinavia and, accordingly, to put the later Mesolithic period, and possibly the transition to a Neolithic lifestyle, with a contemporaneous continuation of a foraging lifestyle e.g. the Pitted Ware culture (Mittnik et al., 2018), within a contextual framework. Consequently, the following inferences can be made.

- A heavy reliance on aquatic resources can be demonstrated in the Early Mesolithic period. It was primarily based on marine resources in marine environments, and on freshwater resources in freshwater environments.
- People were able to ferment (and probably dry and smoke) large amounts of fish and store it for later use, which implies the practice of delayed-return subsistence strategies.
- With a high reliance on fish and year-round seasonality indicators in the Early Mesolithic period, the first suggestions of sedentary settlements appear. These were located in ecotones, i.e. areas, where they could utilize the naturally high biomass in shallow lakes and the seasonal abundance provided by fish spawning migrations, and where they could optimally exploit as many biotopes as possible.
- The locations in the landscape where this type of exploitation was possible became more and more important and, even though hunting was conducted in inland areas, to secure a steady supply of raw material, littoral hot-spots became the areas where territoriality emerged.
- A sedentary lifestyle combined with mass catching technologies, and the means of large-scale food preservation in combination with increasing population densities and territorial displays, indicate the emergence of social complexity in Scandinavia.
- The Early Mesolithic landscape was, however, not crowded and, accordingly, the strict rules that were enforced in the most segregated societies on the north-west coast of America were not implemented in Early Mesolithic southern Scandinavia. There is some evidence, albeit weak, that people had started to control the landscape through claims of heritage. Whereby it is possible that people were practising territoriality

through displayed excarnations and/or located cemeteries in now submerged coastal areas.

- Even though evidence is scarce and limited information is available from the Early Mesolithic coast, subsistence strategies appears to become more and more homogenized during the Mesolithic period. In the Middle Mesolithic period subsistence strategies seemingly followed a general pattern throughout southern Scandinavia. This pattern suggests a developed territoriality, with different human groups operating within their own territories and consequently following similar subsistence patterns based on a high reliance on aquatic resources; this would have been the most efficient way to meet the population's dietary demands when mobility through another group's territory became more restricted.

10. Final reflections

With this thesis, I hopefully leave the Mesolithic period somewhat better understood. It is my hope that the results, as presented here, can make a mark on Mesolithic research and leave colleagues better informed when interpreting this time period. With the evidence gained from the zooarchaeological material, it becomes possible to draw new conclusions from within a framework of available subsistence strategies and with a new set of societal implications in mind. This can only be done, however, while taking into consideration the huge taphonomic imprint that will have affected all the organic archaeological material, from the decision to hunt, fish or gather a certain product, to the final interpretations of the society and/or culture, etc., that have been made today. By considering the taphonomic imprint, and the different factors that have affected the zooarchaeological material, new questions can be raised, not only based on the recovered material, but also concerning the materials that have not been recovered, i.e. by seeking knowledge and insight regarding whether the material in question is missing because it was not exploited or because it has not survived as a result of preservation and/or recovering biases. By using zooarchaeological data in this way, a contextual framework can be created that can assist in deducing information from sites without any preserved organic material, thus aiding general archaeological interpretations.

It is my hope that new sites with organic preservation will be found before soil acidification and drainage, caused by our modern lifestyle, have destroyed all the organic remains from the most vulnerable parts of our cultural heritage, i.e. the oldest remains. In addition, if such sites are found and excavated, it is my hope that the potential of the bones from these sites will be recognized and appropriate measures taken to secure them, prioritize their research and obtain sufficient funds so that they can be analysed and interpreted in full. Animal bones hold one of the keys to understanding the past, and without them interpretations of ancient societies are truly impoverished. Consequently, and allowing myself some progressive thinking (albeit in a wishful spirit), I would like to highlight a few topics for further consideration.

- The sites I have used in this study are the only available coastal Early Mesolithic settlements from Scandinavia with preserved organic remains. Even though the results presented here, hopefully, will change how the period in question is perceived, new sites are sorely needed. Both to test the results at new sites, while conducting the excavations in line with the information generated here, and to study new patterns. While these sites are difficult to locate and are very rare, they still exist. If exploitations are to be made in areas were such sites can exist, it is important that proper surveys and preliminary investigations are carried out. Preliminary excavations should be done using all currently available methods to locate the sites, including deep trenching, so that nothing is missed or overlooked. Thorough and well-executed preliminary excavations are advocated as the means to facilitate the final rescue excavation of these sites, providing a strong, reliable foundation from which to make appropriate excavation plans and cost calculations. This should reduce the risk of not finding the oldest (and most difficult to find) sites, while at the same time minimizing the risk of encountering unforeseen circumstances that have not been budgeted for that could force the excavator to redistribute funds from other areas, which, in the initial excavation plans, were deemed important.

- The results generated by this study highlights, as have so many studies before, the need to apply fine mesh sieves when excavating fish bones. Therefore, there is a strong need to apply even finer mesh sizes than we used at Norje Sunnansund on large-scale excavations. This cannot be stated strongly enough, and is a plea to the county antiquity boards that judge the scientific quality and aims of upcoming exploitation bids from different archaeological sectors. In other words, if we are to be able to understand the area, settlement, grave or time period in question and not just reproduce old knowledge, we must apply ourselves and not be overly concerned with monetary costs. In terms of contract archaeology, the scientific questions and aims must be given top priority by the deciding organizations. If the price tag on a project is the main focus, ‘competition’ lowers the price to such a level that the purpose behind cultural heritage legislation is in danger. Put simply, there is a common interest in archaeology in the general society[90] and a general need to decipher our human origins and anchor our modern society in the past. In order to make any claim of being able to decipher this information and bring forth an interpretation, we must apply ourselves and use the knowledge we have to interpret the archaeological remains, even if it is more costly and time consuming. If we do not, I would argue that there is no point in doing archaeology in the first place, because we would then only reproduce old results and not further our understanding of the past.
- When carrying out preliminary surveys and excavations, it is important that wetland areas, bogs, mires and lake/sea bottoms, affected by planned construction or exploitation, are properly investigated, even though they

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[90] A simple newspaper search and count of articles dealing with archaeological finds should clarify these arguments.

are more difficult to examine compared with a terrestrial location. The potential for organic preservation in these types of environments often surpasses terrestrial environments, and the information from them must be obtained properly in order to advance our knowledge of prehistoric societies.

- When planning and executing large-scale encroachments into cultural layers with preserved organic remains, it is important to consider the diagenetic effects of added oxygen in previously undisturbed and anaerobic layers. Furthermore, if the intended construction[91] requires drainage of the area (which is the case for most roads and buildings), proper investigation into how the organic remains will be affected outside the actual perimeters of the construction must be carried out. Ancient organic remains deprived of the buffering subsoil water will start to degenerate with the removal of the water, and large areas outside a construction zone will be subjected to massive destruction and could experience a complete loss of organic materials within a few years after an area is drained. If appropriate measures are not taken, often involving excavations well outside the areas being exploited, I would argue that the cultural heritage legislation is not being met[92], because destruction, following exploitation, is allowed without archaeological documentation.

- When studying prehistory by means of 'new' methods, e.g. through means of stable isotopes, we must remember that it is a proxy for something else (in the case of $\delta^{13}C$ and $\delta^{15}N$ stable isotopes in collagen, they are a proxy for dietary protein). Therefore, it becomes increasingly important that we always continue to question how these methods are presented and develop alternative ways of interpreting the signals produced. Bearing in mind the results presented here, it is strongly suggested that isotope signals are modelled with methods that are able to consider different types of variation and that isotope values are not presented, merely, as bivariate static graphs. Thinking progressively, perhaps the next step taken should include Baesian mixing models where bulk collagen values are combined with compound-specific collagen data to generate even more high resolution dietary estimations.

- In this thesis subsistence strategies and resource exploitation have been studied to investigate the level of sedentism and territoriality, in order to examine complexity among ancient Scandinavian foragers. However, in order to interpret complexity fully and thoroughly, other areas need to be

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[91] In other words, the construction planned for the location after the rescue excavation.

[92] In Swedish contexts cf. Kulturmiljölagen 2 kap. § 12-13, and in European contexts cf. The European Convention on the Protection of the Archaeological Heritage 1992 article 3.

investigated. These include, among many other things, the recovery of more houses and living areas, graves, grave goods, tribal war indicators and displays of interpersonal violence, etc. It would be fruitful if someone else could pick up the baton and continue this work in other areas, to enlighten the discussion from different angles and with new scientific evaluations of the material.

10.1. The enigmatic fish

Fish live in a different environment than humans, they abide by different laws and they are hidden from our senses until we enter their realm, remove them from their world and transfer them to our domain. The nature of the water is fundamental to understanding human–fish interactions. When hunting terrestrial mammals, you can follow tracks, hear sounds and see the animals, which means you 'know' the animals are there; they are solid. The same is not true for fish, it is impossible to follow a fish in the water; it is either there or not. You cannot smell them, there are no tracks of their presence and they move seemingly without sound. Therefore, it is only through knowledge of how different fish species feed, migrate, breed and live that you are able to truly take advantage of the riches hidden below the surface of the water, to 'know' exactly how and where to look for fish. The attributes of water may in fact be considered something unnatural and mystical (from a terrestrial point of view).

It is not a coincidence that many water bodies have been at the centre of rituals and sacred behaviour throughout millennia of human existence (Berggren, 2010), which is clearly evident in Scandinavia from the numerous open water or wetland depositions that have been found from the Neolithic (Berggren, 2010; Boethius, 2009; Karsten, 1994; Larsson, 2007), Bronze Age (Fredengren, 2011; Vandkilde, 1996) and Iron Age (Hagberg et al., 1977; Stjernquist, 1997). These attributes of water are apparent in foraging societies as well. Even though a continuity between Late Mesolithic and Neolithic water axe depositions has been suggested by Karsten (1994:166), far older and heterogeneous wetland depositions, e.g. Early Mesolithic elk bones deposited at Skottemarke, Favrbo and Lundby in Denmark (Møhl, 1978; Møller Hansen, 2000), impaled human skulls deposited in water at Motala, Sweden (Hallgren, 2011), ritually deposited jaws from different species at Syltholm, Denmark (Sørensen, 2016b), and wild boar jaws deposited in Sludegårds bog, Denmark (Noe-Nygaard and Richter, 1991), indicate that it is the attributes of the water that makes it universally and temporally independent as a sacred place.

In this thesis, however, focus is not on beliefs, the supernatural or even the abstract. Instead, attention has been drawn to one of the most basal and fundamental of human needs: the need to eat, or, more accurately, the strategies taken to secure a consistent food supply, and the implications thereof. Consequently, the arguments have often revolved around the importance of fish and fishing when explaining Early Holocene subsistence strategies. As a result of circling around this topic, the rules applied to fish and fishing become central to understanding their importance. It has, e.g., been shown in detail how fish bones tend to vanish more easily than mammal bones[93], both as a result of them being smaller and therefore harder to find during excavations, but also because they are more fragile and disintegrate faster than bones from mammals and birds. In some ways these attributes are reminiscent of the attributes of the fish themselves, i.e. they can appear mysterious and hard to catch but, once you have applied the right methods and found the right places, they will appear in large quantities.

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[93] Highlighting the implications for our current understanding of Mesolithic subsistence in general.

11. Sammanfattning (Swedish summary)

Syftet med föreliggande avhandling är att utvärdera och tolka de näringsstrategier som stod till buds för den jägar-samlar-fiskarpopulation som bebodde södra Skandinavien under tidig Holocen. I avhandlingen har ett tvärvetenskapligt förhållningssätt applicerats på zooarkeologisk data i syfte att studera olika aspekter av tidig- och mellanmesolitiskt näringsfång, vilket har möjliggjort diskussioner kring hur valda strategier påverkar livet för tidiga Nordeuropeiska samhällen.

Tre boplatser/områden är i fokus i avhandlingen nämligen Norje Sunnansund i Blekinge, Huseby Klev i Bohuslän samt Gotland/Gisslause i Östersjön. De tre utvalda områdena utgör de enda kända tidigmesolitiska kustnära områden med välbevarat organiskt material. Bristen på välbevarat organiskt material problematiseras i avhandlingen och relateras till vår förståelse för fiskets betydelse under tidigholocen. För att möjliggöra en holistisk diskussion har allt tillgängligt osteologiskt material från tidig- och mellanmesolitiska södra Skandinavien använts och relaterats till övrig arkeologisk data.

I syfte att synliggöra olika aspekter av tidig- och mellanmesolitiskt näringsfång har renodlade zooarkeologiska analyser kombinerats med statistiska-, kemiska-, fysikaliska-, kvartärgeologiska och etnografiska analysmetoder och förhållningssätt. I avhandlingens olika delar växlar fokus mellan fiskfermentering som ett sätta att konservera mat, till diskussioner rörande bevis för fördröjd konsumtion och sedentism i sedan länge försvunna jägar-fiskar-samlarsamhällen.

Tafonomi är ytterligare ett område som lyfts fram i avhandlingen. Tafonomiska förhållningssätt används för att kunna adressera de många felkällor som påverkar förståelsen, bevarandet och tillvaratagandet av ett sötvattenfiskbensmaterial och dess implikationer för att spåra en mänsklig diet baserad på sötvattensfiske. I syfte att hitta nya vägar för att angripa denna fråga har även sötvattenreservoareffekten i mänskligt kollagen från Gotland utvärderats. Vidare har tillgängliga benmaterial från den svenska västkusten studerats, vilket möjliggjort en diskussion om marina pionjärbosättares näringsstrategier samt hur deras näringsfång och resurs-utnyttjande, förändrades och utvecklades över tid. Slutligen har stabila kol- och kväveisotoper ($\delta^{13}C$ och $\delta^{15}N$) hos tidiga- och mellanmesolitiska människor analyserats, modellerats och relaterats till isotopvärden från tänkbara födokällor. Detta gjordes med syfte att utvärdera betydelsen av individuella näringskällor i den samlade mänskliga proteinkonsumtionen.

De olika studiernas resultat är samstämmiga och indikerar att den mänskliga dieten var baserad på fisk i en betydligt större utsträckning och från ett tidigare datum än vad som tidigare antagits. Detta har i sin tur betydelse för vår förståelse för tidigholocena samhällen och resultaten som presenteras i avhandlingen antyder att de mänskliga samhällena blev mer och mer bofasta, vilket föranledde territoriella yttringar. Sammantaget indikerar resultaten i avhandlingen att en begynnande social stratifiering är tänkbar för tidigholocena Skandinaviska fiskar-jägar-samlarsamhällen.

12. References

Aaris-Sørensen, K. 1976. A zoological investigation of the bone material from Sværdborg I–1943. *In:* Henriksen, B. (ed.) *Sværdborg I. excavations 1943-44. a settlement of the Maglemose culture. Arkeologiske Studier, vol 3.* 137-148. Copenhagen: Akademisk Forlag.

Aaris-Sørensen, K. 1980. Depauperation of the mammalian fauna of the island of Zealand during the Atlantic period. *Videnskabelige Meddelelser fra dansk naturhistorisk Forening,* 142**,** 131-138.

Adán, G. E., Álvarez-Lao, D., Turrero, P., Arbizu, M. & García-Vázquez, E. 2009. Fish as diet resource in North Spain during the Upper Paleolithic. *Journal of Archaeological Science,* 36**,** 895-899.

Ahlström, T. 2001. De dödas ben. Osteologisk analys av människobenen från Tågerup. *In:* Karsten, P. & Knarrström, B. (eds.) *Tågerup specialstudier.* 70-81. Lund: UV Syd, Avd. för arkeologiska undersökningar.

Aigner, J. S. & Veltre, D. 1976. The distribution and pattern of Umqan burial on southwest Umnak Island. *Arctic Anthropology,* 13.2**,** 113-127.

Alley, R. B. & Ágústsdóttir, A. M. 2005. The 8k event: cause and consequences of a major Holocene abrupt climate change. *Quaternary Science Reviews,* 24**,** 1123-1149.

Althin, C.-A. 1954. *The Chronology of the Stone Age Settlement of Scania, Sweden,* Acta Archaeologica Lundensia. Series in 4°, 1*,* Lund.

Ambrose, S. H. 1990. Preparation and characterization of bone and tooth collagen for isotopic analysis. *Journal of archaeological science,* 17**,** 431-451.

Ambrose, S. H. 2000. Controlled diet and climate experiments on nitrogen isotope ratios of rats. *In:* Ambrose, S. H. & Katzenberg, M. A. (eds.) *Biogeochemical approaches to paleodietary analysis.* 243-259. New York: Kluwer academic publishers.

Ames, K. M. 1981. The evolution of social ranking on the Northwest Coast of North America. *American Antiquity,* 46**,** 789-805.

Ames, K. M. 1985. Hierarchies, stress, and logistical strategies among hunter-gatherers in northwestern North America. *In:* Price, D. T. & Brown, J. A. (eds.) *Prehistoric hunter-gatherers: The emergence of cultural complexity.* 155-180. New York: Academic Press.

Ames, K. M. 1994. The Northwest Coast: Complex hunter-gatherers, ecology, and social evolution. *Annual Review of Anthropology,* 23**,** 209-229.

Ameziane, J. 2009. *Mesolitiska och Neolitiska landskapsrum. Arkeologiska undersökningar av stenålderns boplatser i Jönköpings län,* Arkeologisk rapport 2009:38*,* Jönköping: Jönköpings Läns Museum.

Andersen, K., Jørgensen, S. & Richter, J. 1982. *Maglemose hytterne ved Ulkestrup Lyng,* Copenhagen: Kongelige Nordiske Oldskriftselskab.

Andersson, H. 2016. *Gotländska stenåldersstudier: Människor och djur, platser och landskap.* Stockholm University.

Apel, J. & Hongslo Vala, C. 2013. *Stenålderslokalen Gisslause I Lärbro sn (raä 413:1),* Unpublished report. Visby: Gotland University.

Apel, J. & Storå, J. 2017. The Pioneer settlements of Gotland—a behavioural ecology approach. *In:* Persson, P., Skar, B., Breivik, H. M., Riede, F. & Jonsson, L. (eds.) *The Ecology of Early Settlement in Northern Europe: Conditions for Subsistence and Survival.* Sheffield: Equinox.

Apel, J., Wallin, P., Storå, J. & Possnert, G. 2017. Early Holocene human population events on the island of Gotland in the Baltic Sea (9200-3800 cal. BP). *Quaternary International,* In Press.

Arnesson-Westerdahl, A. 1984. *Den tidigmesolitiska faunan vid Hornborgasjön, Västergötland. Osteologisk analys av djurbensmaterialet från 1983 års arkeologiska undersökningar på Almeö 96 B,* Unpublished report.

Arwidsson, G. 1979. Stenåldersmannen från Stora Bjärs i Stenkyrka. *In:* Falck, W., Nylén, E., Nylén, K., Schönbäck, B. & Svahnström, K. (eds.) *Arkeologi på Gotland.* 17-23. Visby: Gatlandica.

Ascough, P., Cook, G., Church, M., Dunbar, E., Einarsson, Á., McGovern, T., Dugmore, A., Perdikaris, S., Hastie, H. & Friðriksson, A. 2010. Temporal and spatial variations in freshwater 14 C reservoir effects: lake Mývatn, Northern Iceland. *Radiocarbon,* 52**,** 1098-1112.

Aura, T., JE , Pardo, J. J., Ripoll, M. P., García, M. R., García, E. B. & Calatayud, P. G. 2002. The far south: the Pleistocene–Holocene transition in Nerja Cave (Andalucıa, Spain). *Quaternary International,* 93**,** 19-30.

Bailey, G. 2014. New developments in submerged prehistoric archaeology: an overview. *In:* Evans, A. M., Flatman, J. C. & Flemming, N. C. (eds.) *Prehistoric archaeology on the continental shelf: a global review.* 291-300. New York: Springer.

Bailey, G. & Milner, N. 2002. Coastal hunter-gatherers and social evolution: marginal or central? *Before farming,* 2002**,** 1-22.

Barnosky, A. 1989. The late Pleistocene event as a paradigm for widespread mammal extinction. *In:* Donovan, S. (ed.) *Mass extinctions: processes and evidence.* 235-54. London: Belhaven.

Barnosky, A. D. & Lindsey, E. L. 2010. Timing of Quaternary megafaunal extinction in South America in relation to human arrival and climate change. *Quaternary International,* 217**,** 10-29.

Bay-Petersen, J. 1978. Animal exploitation in mesolithic Denmark. *In:* Mellars, P. (ed.) *The Early Postglacial Settlement of Northern Europe: An Ecological Perspective.* 115-146. London: Duckworth.

Bearhop, S., Adams, C. E., Waldron, S., Fuller, R. A. & MacLeod, H. 2004. Determining trophic niche width: a novel approach using stable isotope analysis. *Journal of animal ecology,* 73**,** 1007-1012.

Becker, C. J. 1945. En 8000-aarig stenalderboplads i Holmegaards Mose. *Nationalmuseets arbejdsmark,* 1945**,** 61-72.

Beh, E. J. & Lombardo, R. 2014. *Correspondence analysis: theory, practice and new strategies,* West Sussex: John Wiley & Sons.

Bengtson, S.-A. 1984. Breeding ecology and extinction of the Great Auk (Pinguinus impennis): anecdotal evidence and conjectures. *The Auk,* 101**,** 1-12.

Berggren, Å. 2010. *Med kärret som källa: om begreppen offer och ritual inom arkeologin,* Lund: Nordic Academic Press.

Bergsvik, K. A. & David, É. 2015. Crafting bone tools in mesolithic Norway: A regional eastern-related know-how. *European Journal of Archaeology,* 18**,** 190-221.

Bērziņš, V. 2010. Fishing seasonality and techniques in prehistory; why freshwater fish are special. *Archaeologia Baltica,* 13**,** 37-42.

Binford, L. R. 1980. Willow smoke and dogs' tails: hunter-gatherer settlement systems and archaeological site formation. *American antiquity,* 45**,** 4-20.

Binford, L. R. 1990. Mobility, housing, and environment: a comparative study. *Journal of Anthropological Research,* 46**,** 119-152.

Binford, L. R. 2001. *Constructing frames of reference: an analytical method for archaeological theory building using ethnographic and environmental data sets,* Berkeley: University of California Press.

Birdsell, J. B. 1968. Some Predictions for the Pleistocene Based On Equilibrium Systems Among Recent Hunter-Gatherers. *In:* Lee, R. & DeVore, I. (eds.) *Man the Hunter.* 229-240. Chicago: Aldine.

Bjerck, H. B. 1994. Nordsjøfastlandet og pionerbosetningen i Norge. *Viking,* 57**,** 25-58.

Bjerck, H. B. 2007. Mesolithic coastal settlements and shell middens in Norway. *In:* Milner, N., Craig, O. E. & Bailey, G. (eds.) *Shell Middens in Atlantic Europe.* 5-30. Oxford: Oxbow Books.

Bjerck, H. B. 2009. Colonizing seascapes: comparative perspectives on the development of maritime relations in Scandinavia and Patagonia. *Arctic Anthropology,* 46**,** 118-131.

Bjerck, H. B. 2016. Settlements and Seafaring: Reflections on the Integration of Boats and Settlements Among Marine Foragers in Early Mesolithic Norway and the Yámana of Tierra del Fuego. *The Journal of Island and Coastal Archaeology,* 12.2**,** 1-24.

Björk, T., Henriksson, M., Larsson, F., Persson, C., Rudebeck, E. & Åstrand, J. 2016. *Lussabacken norr. Boplatslämningar från mesolitikum, neolitikum, bronsålder och järnålder. Särskild arkeologisk undersökning 2011. Ysane socken, Sölvesborgs kommun i Blekinge län,* Blekinge Museum Rapport 2014:9*,* Karlskrona: Blekinge Museum.

Björk, T., Knarrström, B. & Persson, C. 2015. *Damm 6 och Bro 597. Boplatslämningar och en hydda från tidigmesolitikum. Särskild arkeologisk undersökning 2011 och arkeologisk förundersökning 2012 Ysane socken, Sölvesborgs kommun i Blekinge län,* Blekinge museum rapport 2014:14*,* Karlskrona: Blekinge Museum.

Bjørklund, I. 2013. Domestication, reindeer husbandry and the development of Sámi pastoralism. *Acta Borealia,* 30**,** 174-189.

Blankholm, H. P. 1994. Some final words on Stapert's treatment of Barmose I. *Palaeohistoria,* 33/34**,** 63-64.

Blankholm, H. P. 1996. *On the track of a prehistoric economy: Maglemosian subsistence in early postglacial South Scandinavia,* Aarhus: Aarhus Universitetsforlag.

Blankholm, H. P. 2008. Southern Scandinavia. *In:* Bailey, G. & Spikins, P. (eds.) *Mesolithic Europe.* 107-131. Cambridge Cambridge University Press.

Boas, F. 1897. *The social organization and the secret societies of the Kwakiutl Indians,* Report of the U.S. National Museum, 1895*,* Washington D.C: U.S. National Museum.

Boas, F. 1966. *Kwakiutl ethnography,* edited by Codere, H. Chicago: University of Chicago Press.

Bocherens, H. & Drucker, D. 2003. Trophic level isotopic enrichment of carbon and nitrogen in bone collagen: case studies from recent and ancient terrestrial ecosystems. *International Journal of Osteoarchaeology,* 13**,** 46-53.

Boethius, A. 2009. Lindängelund - en osteologisk analys om offer och gropar. *Reports in osteology 2009:1.* Lund: Institutionen för arkeologi och antikens historia, Lunds universitet.

Boethius, A. 2016a. Osteologiska analyser av det mesolitiska materialet *In:* Kjällquist, M., Emilsson, A. & Boëthius, A (ed.) *Norje Sunnansund. Boplatslämningar från tidigmesolitikum och järnålder. Särskild arkeologisk undersökning 2011 och arkeologisk förundersökning 2011 och 2012, Ysane socken, Sölvesborgs kommun i Blekinge län.* Karlskrona: Blekinge museum.

Boethius, A. 2016b. Something rotten in Scandinavia: The world's earliest evidence of fermentation. *Journal of Archaeological Science,* 66**,** 169-180.

Boethius, A. 2017. Signals of sedentism: Faunal exploitation as evidence of a delayed-return economy at Norje Sunnansund, an Early Mesolithic site in south-eastern Sweden. *Quaternary Science Reviews,* 162**,** 145-168.

Boethius, A. 2018a. Huseby klev and the quest for pioneer subsistence strategies: Diversification of a maritime lifestyle. *In:* Persson, P., Skar, B., Breivik, H. M., Riede, F. & Jonsson, L. (eds.) *The Ecology of Early Settlement in Northern Europe - Conditions for Subsistence and Survival.* 99-128. Sheffield: Equinox.

Boethius, A. 2018b. The use of aquatic resources by Early Mesolithic foragers in southern Scandinavia. *In:* Persson, P., Skar, B., Breivik, H. M., Riede, F. & Jonsson, L. (eds.) *The Ecology of Early Settlement in Northern Europe - Conditions for Subsistence and Survival.* 311-334. Sheffield: Equinox.

Boethius, A. & Ahlström, T. 2018. Fish and resilience among early Holocene foragers of southern Scandinavia: a fusion of stable isotopes and zooarchaeology through Bayesian mixing modelling. *Journal of Archaeological Science*, 93, 196-210.

Boethius, A. & Magnell, O. 2010. Osteologisk analys av benmaterialet från område 12 förundersökning inför utbyggnad av E22 sträckan Sölve-Stensnäs. *Reports in Osteology 2010:7.* Uppdrag Osteologi, Lunds Universitet, Institutionen för Arkeologi och Antikens historia.

Boethius, A., Storå, J., Hongslo Vala, C. & Apel, J. 2017. The importance of freshwater fish in Early Holocene subsistence: exemplified with the human colonization of the island of Gotland in the Baltic basin. *Journal of Archaeological Science: Reports,* 13**,** 625–634.

Bokelmann, K. 1986. Rast unter Bäumen. Ein ephemerer mesolithischer Lagerplatz aus dem Duvenseer Moor in Festschrift Albert Bantelmann. *Offa,* 43**,** 149-163.

Borrman, H., Engström, E., Alexandersen, V., Jonsson, L., Gerdin, A. & Carlsson, G. 1995. Dental conditions and temporomandibular joints in an early mesolithic bog man. *Swedish dental journal,* 20**,** 1-14.

Bosold, K. 1968. Geschlechts-und Gattungsunterschiede an Metapodien und Phalangen mitteleuropäischer Wildwiederkäuer. *Säugetierkundliche Mitteilungen,* 16**,** 93-153.

Brännborn, P., Jardfelt, J. & Karlsson, A. 2008. *Fågel, Fisk och mitt i mellan-Osteologisk analys av materialet från mesolitiska-neolitiska boplatsen Sjöholmen,* Unpublished seminar paper in Historical Osteology*,* Lund: Department of Archaeology and Ancient History, Lund University.

Brillat-Savarin, J. A. 1994. *The Physiology of Taste,* London: Penguin Books.

Brinch Petersen, E. 2015. *Diversity of mesolithic Vedbæk,* Acta Archaeologica 86:1. Centre of World Archaeology (CWA) 12*,* Oxford: Wiley.

Brinch Petersen, E. 2016. Afterlife in the Danish Mesolithic the creation, use and discarding of Loose Human Bones. *In:* Grünberg, J. M., Gramsch, B., Larsson, L., Orschiedt, J. & Meller, H. (eds.) *Mesolithic Burials–Rites, Symbols and Social Organisation of Early Postglacial Communities. International Conference Halle (Saale), Germany, 18th-21st September 2013.***,** 47-62. Halle: Landesmuseum Halle.

Brinch Petersen, E. & Rosenlund, K. 1972. Svaerdborg II: A Maglemose hut from svaerdborg bog, Zealand, Denmark. *Acta Archaeologica,* 42**,** 43-77.

Brodie, C. R., Leng, M. J., Casford, J. S., Kendrick, C. P., Lloyd, J. M., Yongqiang, Z. & Bird, M. I. 2011. Evidence for bias in C and N concentrations and δ 13 C composition of terrestrial and aquatic organic materials due to pre-analysis acid preparation methods. *Chemical Geology,* 282**,** 67-83.

Broholm, H., Jessen, K. & Winge, H. 1924. Nye fund fra den ældste stenalder. Homegaard- og Sværdborgfundene. *Aarbøger for Nordisk oldkyndighed og historie,* 1924**,** 1-144.

Brook, B. W. & Johnson, C. N. 2006. Selective hunting of juveniles as a cause of the imperceptible overkill of the Australian Pleistocene megafauna. *Alcheringa: an Australasian journal of palaeontology,* 30**,** 39-48.

Brown, T. A., Nelson, D. E., Vogel, J. S. & Southon, J. R. 1988. Improved collagen extraction by modified Longin method. *Radiocarbon,* 30**,** 171-177.

Bull, G. & Payne, S. 1982. Tooth eruption and epiphysial fusion in pigs and wild boar. *In:* Wilson, B. (ed.) *Ageing and sexing animal bones from archaeological sites.* British series 109. 55-71. Oxford: BAR.

Burenhult, G. 1999. *Arkeologi i Norden,* Stockholm: Natur och Kultur.

Burley, D. V. 1980. *Marpole Anthropological Reconstructions of a Prehistoric Northwest Coast Culture Type,* Dept. Archaeo. Pub. No. 8. *,* Burnaby: Simon Fraser Univ.

Busekist, J. v. 2004. Bone Base Baltic Sea, . *A computer supported identification system for fish bones. Version 1.0 for MS-Windows CD-ROM.* http://www.bioarchiv.de. Germany: University of Rostock.

Butler, V. L. & Chatters, J. C. 1994. The role of bone density in structuring prehistoric salmon bone assemblages. *Journal of Archaeological Science,* 21**,** 413-424.

Butler, V. L. & Schroeder, R. A. 1998. Do digestive processes leave diagnostic traces on fish bones? *Journal of Archaeological Science,* 25**,** 957-971.

Calvin, M. & Benson, A. A. 1948. *The path of carbon in photosynthesis,* Berkeley: US Atomic Energy Commission, Technical Information Division.

Cannon, A. & Yang, D. Y. 2006. Early storage and sedentism on the Pacific northwest coast: ancient DNA analysis of salmon remains from Namu, British Columbia. *American Antiquity,* 71**,** 123-140.

Cardell, A. 2004. Fish Bones from the Late Atlantic Ertebølle Settlement of Møllegabet II. *In:* Grøn, O. & Skaarup, J. (eds.) *Møllegabet II. A submerged Mesolithic settlement in southern Denmark.* 148-158. Langelands Museum: Archaeopress.

Carlsson, T. 2008. *Where the river bends under the boughs of trees: Strandvägen-a late mesolithic settlement in eastern middle Sweden,* Stockholm: Riksantikvarieämbetet.

Carter, R. J. 2001. Dental indicators of seasonal human presence at the Danish Boreal sites of Holmegaard I, IV and V and Mullerup and the Atlantic sites of Tybrind Vig and Ringkloster. *The Holocene,* 11**,** 359-365.

Cartwright, N. & Montuschi, E. 2014. *Philosophy of social science: A new introduction*: Oxford University Press, USA.

Casati, C. & Sørensen, L. 2012. Two hut structures from an Early Mesolithic site at Ålyst (Denmark). A preliminary report. *In:* S. Gaudzinski-Windheuser, O. J., M. Sensburg, M. Street, E. Turner (ed.) *Site-internal Spatial Organization of Hunter-gatherer Societies: Case Studies From the European Palaeolithic and Mesolithic. Papers Submitted at the Session (C58) "Come in ... and find out: Opening a New door Into the analysis of hunter-gatherer social organization and behavior", Held at the 15th U.I.S.P.P. Conference in Lisbon, September 2006.* 175-186. Mörlenbach: Verlag des Römisch-Germanischen Zentralmuseums.

Cashdan, E. 1983. Territoriality among human foragers: ecological models and an application to four Bushman groups. *Current anthropology,* 24**,** 47-66.

Casteel, R. W. 1972. Some archaeological uses of fish remains. *American Antiquity,* 37**,** 404-419.

Casteel, R. W. 1974. A method for estimation of live weight of fish from the size of skeletal elements. *American Antiquity,* 39**,** 94-98.

Casteel, R. W. 1976a. Comparison of column and whole unit samples for recovering fish remains. *World Archaeology,* 8**,** 192-196.

Casteel, R. W. 1976b. *Fish remains in archaeology and paleo-environmental studies,* London: Academic Press.

Caut, S., Angulo, E. & Courchamp, F. 2008. Discrimination factors (Δ15N and Δ13C) in an omnivorous consumer: effect of diet isotopic ratio. *Functional Ecology,* 22**,** 255-263.

Caut, S., Angulo, E. & Courchamp, F. 2009. Variation in discrimination factors (Δ15N and Δ13C): the effect of diet isotopic values and applications for diet reconstruction. *Journal of Applied Ecology,* 46**,** 443-453.

Choy, K., Potter, B. A., McKinney, H. J., Reuther, J. D., Wang, S. W. & Wooller, M. J. 2016. Chemical profiling of ancient hearths reveals recurrent salmon use in Ice Age Beringia. *Proceedings of the National Academy of Sciences,* 113**,** 9757-9762.

Christensson, V. 2015. *Vilt i området kring kustboplatsen Huseby klev En analys av vilt som påträffats i det osteologiska materialet inom Huseby klev från tidigmesolititkum,* Unpublished seminar paper in Historical Osteology*,* Department of Archaeology and Ancient History: Lund University.

Clark, G. 1946. Seal Hunting in the Stone Age of North-Western Europe: a Study in Economic Prehistory. *Proceedings of the Prehistoric Society,* 12**,** 12-48.

Clark, G. 1948. The development of fishing in prehistoric Europe. *The Antiquaries Journal,* 28**,** 45-85.

Clark, G. 1976. A Baltic Cave Sequence: A Further Study in Bioarchaeology. *Archaeologia Austriaca,* 13**,** 113-23.

Cohen, J. E. 1994. Marine and Continental Food Webs: Three Paradoxes? *Philosophical Transactions of the Royal Society of London,* B 343**,** 57-69.

Conard, N. J., Kitagawa, K., Krönneck, P., Böhme, M. & Münzel, S. C. 2013. The importance of fish, fowl and small mammals in the Paleolithic diet of the Swabian Jura, Southwestern Germany. *In:* Clark, J. M. & Speth, J. D. (eds.) *Zooarchaeology and Modern Human Origins: Human Hunting Behavior During the Later Pleistocene.* 173-190. Dordrecht: Springer.

Corbett, D. G., West, D. & Lefevre, C. 2001. Prehistoric village organization in the western Aleutians. *In:* Dumond, D. (ed.) *Archaeology in the Aleut zone of Alaska: Some recent research.* 251-266. Eugene: University of Oregon.

Costa, A. P. B. & Simões-Lopes, P. C. 2012. Physical maturity of the vertebral column of Tursiops truncatus (Cetacea) from Southern Brazil. *Neotropical Biology and Conservation,* 7**,** 2-7.

Coularis, C., Tisnérat-Laborde, N., Pastor, L., Siclet, F. & Fontugne, M. 2016. Temporal and Spatial Variations of Freshwater Reservoir Ages in the Loire River Watershed. *Radiocarbon,* 58**,** 549-563.

Cummings, V., Jordan, P. & Zvelebil, M. 2014. *The Oxford Handbook of the Archaeology and Anthropology of Hunter-gatherers,* Oxford: Oxford University Press.

Cunningham, P. 2011. Caching your savings: The use of small-scale storage in European prehistory. *Journal of Anthropological Archaeology,* 30**,** 135-144.

Curry-Lindahl, K. 1969. *Fiskarna i färg,* Stockholm: Almqvist & Wiksell.

Cziesla, E. 2004. Late Upper Palaeolithic and Mesolithic cultural continuity: or: bone and antler objects from the Havelland. *In:* Terberger, T. I. & Eriksen, B. V. (eds.) *Hunters in a changing world. UISPP commission XXXII, Workshop Greifswald September 2002. Internationale Archäologie - Arbeitsgemeinschaft, Symposium, Tagung, Kongress, 5.* Leidorf: Rahden/Westf.

Dalerum, F. & Angerbjörn, A. 2005. Resolving temporal variation in vertebrate diets using naturally occurring stable isotopes. *Oecologia,* 144**,** 647-658.

Damlien, H., Kjällquist, M. & Knutsson, K. 2018. The pioneer settlement of Scandinavia and its aftermath. New evidence from western and central Scandinavia. *In:* Knutsson, K., Knutsson, H., Apel, J. & Glørstad, H. (eds.) *The Technology of Early Settlement in Northern Europe - Transmission of Knowledge and Culture.* Sheffield: Equinox.

David, É. & Kjällquist, M. 2018. Transmission of the Mesolithic Northeastern crafting tradition. The Norje Sunnansund style introduced in the Maglemosian area around 9.3 ka BP. *In:* Glørstad, H., Knutsson, K., Knutsson, H. & Apel, J. (eds.) *The Technology of Early Settlement in Northern Europe - Transmission of Knowledge and Culture.* Sheffield: Equinox.

Degerman, E., Nyberg, P., Näslund, I. & Jonasson, D. 2002. *Ekologisk fiskevård,* Spånga: Sportfiskarna, Sveriges sportfiske- och fiskevårdsförbund.

DeNiro, M. J. 1985. Postmortem preservation and alteration of in vivo bone collagen isotope ratios in relation to palaeodietary reconstruction. *Nature,* 317**,** 806-809.

DeNiro, M. J. & Epstein, S. 1976. You are what you eat (plus a few‰): the carbon isotope cycle in food chains. *Geological Society of America,* 6**,** 834.

DeNiro, M. J. & Epstein, S. 1978. Influence of diet on the distribution of carbon isotopes in animals. *Geochimica et cosmochimica acta,* 42**,** 495-506.

DeNiro, M. J. & Epstein, S. 1981. Influence of diet on the distribution of nitrogen isotopes in animals. *Geochimica et Cosmochimica Acta,* 45**,** 341-351.

Desautels, R. J., McCurdy, A. J., Flynn, J. D. & Ellis, R. R. 1970. *Archaeological Report, Amchitka Island, Alaska, 1969-1970. Report No. TID-25481.,* Archaeological research inc., Washington, DC: US Atomic Energy Commission.

Dolukhanov, P. 2008. The Mesolithic of European Russia, Belarus, and the Ukraine. *In:* Bailey, G. & Spikins, P. (eds.) *Mesolithic Europe.* 280-301. Cambridge: Cambridge University Press.

Efremov, I. A. 1940. Taphonomy: a new branch of paleontology. *Pan-American Geologist,* 74**,** 81-93.

Ekman, J. 1974. Djurbensmaterialet från stenålderslokalen Ire. Hangvar sn, Gotland. . *In:* Janzon, G. (ed.) *Gotlands mellanneolitiska gravar.* 212-246. Stockholm: Almqvist & Wiksell.

Ekström, J. 1993. *The late Quaternary history of the urus (Bos primigenius Bojanus 1827) in Sweden,* Lundqua thesis Lund: Lund University, Department of Quaternary Geology.

Emeis, K.-C., Struck, U., Blanz, T., Kohly, A. & Voβ, M. 2003. Salinity changes in the central Baltic Sea (NW Europe) over the last 10000 years. *The Holocene,* 13**,** 411-421.

Enghoff, I. B. 1987. Freshwater Fishing from a Sea-Coastal Settlement – the Erteбölle locus classicus Revisited. *Journal of Danish Archaeology* Vol. 5**,** 62-76.

Enghoff, I. B. 1989. Fishing from the stone age settlement Norsminde. *Journal of Danish Archaeology,* 8**,** 41-50.

Enghoff, I. B. 1991. Mesolithic eel-fishing at Bjørnsholm, Denmark, spiced with exotic species. *Journal of Danish Archaeology,* 10**,** 105-118.

Enghoff, I. B. 1994. Fishing in Denmark during the Ertebølle period. *International Journal of Osteoarchaeology,* 4**,** 65-96.

Enghoff, I. B. 1995. Fishing in Denmark during the Mesolithic period. *In:* Fischer, A. (ed.) *Man and sea in the Mesolithic : coastal settlement above and below present sea level : proceedings of the international symposium, Kalundborg, Denmark 1993.* 67-74. Oxford: Oxbow.

Enghoff, I. B. 2007. Viking age fishing in Denmark, with particular focus on the freshwater site Viborg, methods of excavation and smelt fishing. *In:* Plogmann, H. H. (ed.) *International Council for Archaeozoology. Fish Remains Working Group. Meeting (2007). The role of fish in ancient time: proceedings of the 13th meeting of the ICAZ Fish Remains Working Group in October 4th - 9th, Basel/Augst 2005.* 69-76. Rahden/Westf: Verlag Marie Leidorf.

Enghoff, I. B. 2011. *Regionality and biotope exploitation in Danish Ertebølle and adjoining periods,* Scientia danica. Series B, Biologica, 1904-5484*,* Copenhagen: Det Kongelige Danske Videnskabernes Selskab.

Enghoff, I. B., MacKenzie, B. R. & Nielsen, E. E. 2007. The Danish fish fauna during the warm Atlantic period (ca. 7000–3900bc): Forerunner of future changes? *Fisheries Research,* 87**,** 167-180.

Ericson, P. G. 1994. Senatlantiska faunalämningar från en boplats vid Leksand, Dalarna. *Fornvännen,* 89**,** 251-256.

Ericson, P. G. & Storå, J. 1999. *A manual to the skeletal measurements of the seal genera Halichoerus and Phoca (Mammalia: Pinnipedia),* Unpublished handout. Stockholm: Department of Vertebrate Zoology, Swedish Museum of Natural History.

Eriksson, G. 2003. *Norm and difference: Stone Age dietary practice in the Baltic region,* Stockholm: Jannes Snabbtryck Kuvertproffset HB.

Eriksson, G., Frei, K. M., Howcroft, R., Gummesson, S., Molin, F., Lidén, K., Frei, R. & Hallgren, F. 2016. Diet and mobility among Mesolithic hunter-gatherers in Motala (Sweden)-The isotope perspective. *Journal of Archaeological Science: Reports,* http://dx.doi.org/10.1016/j.jasrep.2016.05.052.

Eriksson, M. & Magnell, O. 2001. Det djuriska Tågerup. Nya rön kring Kongemose-och Erteböllekulturens jakt och fiske. *In:* Karsten, P. & Knarrström, B. (eds.) *Tågerup. Specialstudier.* 156-237. Lund: UV Syd, Avd. för arkeologiska undersökningar.

Finney, B. P., Gregory-Eaves, I., Douglas, M. S. & Smol, J. P. 2002. Fisheries productivity in the northeastern Pacific Ocean over the past 2,200 years. *Nature,* 416**,** 729-733.

Fischer, A. 1995. *Man and sea in the Mesolithic: coastal settlement above and below present sea level: proceedings of the International Symposium, Kalundborg, Denmark 1993,* Oxford: Oxbow books.

Fischer, A., Møhl, U., Bennike, P., Tauber, H., Malmros, C., Scheu Hansen, J. & Smed, P. 1987. *Argus-grunden - En Undersøisk Boplads fra Jægerstenalderen,* Copenhagen: Skov og Naturstyrelsen.

Fischer, A., Olsen, J., Richards, M., Heinemeier, J., Sveinbjörnsdóttir, Á. E. & Bennike, P. 2007. Coast–inland mobility and diet in the Danish Mesolithic and Neolithic: evidence from stable isotope values of humans and dogs. *Journal of Archaeological Science,* 34**,** 2125-2150.

Fitzhugh, B. 2003. *The Evolution of Complex Hunter-Gatherers Archaeological Evidence from the North Pacific,* Interdisciplinary Contributions to Archaeology*,* New York: Kluwer.

Fjellström, P. 1986. *Samernas samhälle i tradition och nutid,* Stockholm: Norstedt.

Florin, S. T., Felicetti, L. A. & Robbins, C. T. 2011. The biological basis for understanding and predicting dietary-induced variation in nitrogen and sulphur isotope ratio discrimination. *Functional Ecology,* 25**,** 519-526.

Forchhammer, G., Steenstrup, J. & Worsaae, J. 1851. Undersögelser i Geologisk-antiqvarisk Retning (Særskilt optrykt af Oversigten over Videnskabernes Selskabs Forhandlinger i Aarene 1848 og 1851). Copenhagen: Bianco Luno.

Fornander, E. 2011. A shattered tomb of scattered people: the Alvastra Dolmen in light of stable isotopes. *Current Swedish Archaeology,* 19**,** 113-141.

Forssander, J. 1930. En märklig stenåldersboplats vid Sjöholmen. *Meddelanden från Lunds universitets historiska museum,* IV**,** 25-42.

Fredén, C. 1986. *Quaternary marine shell deposits in the region of Uddevalla and Lake Vänern,* Uppsala: Sveriges geologiska undersökning.

Fredén, C. 1988. *Marine life and deglaciation chronology of the Vänern basin, southwestern Sweden,* Göteborg: Chalmers tekniska högskola, Göteborgs universitet, Geologiska institutionen.

Fredengren, C. 2011. Where wandering water gushes–the depositional landscape of the Mälaren Valley in the late Bronze Age and earliest Iron Age of Scandinavia. *Journal of Wetland Archaeology,* 10**,** 109-135.

Friis Johansen, K. 1919. En boplads fra den ældste stenalder I Sværdborg mose. *Aarbøger for Nordisk oldkyndighed og historie,* 1919**,** 106-235.

Frink, L. & Giordano, C. 2015. Women and Subsistence Food Technology: The Arctic Seal Poke Storage System. *Food and Foodways,* 23**,** 251-272.

Gramsch, B., Beran, J., Hanik, S. & Sommer, R. S. 2013. A Palaeolithic fishhook made of ivory and the earliest fishhook tradition in Europe. *Journal of Archaeological Science,* 40**,** 2458-2463.

Gray Jones, A. 2011. *Dealing with the dead: manipulation of the body in the mortuary practices of Mesolithic north-west Europe,* Manchester: The University of Manchester.

Grayson, D. K. 1984. *Quantitative zooarchaeology: topics in the analysis of archaeological faunas,* Orlando: Academic Press.

Greenacre, M. 2007. *Correspondence analysis in practice. 2. ed,* Boca Raton: CRC press.

Grey, J., Jones, R. I. & Sleep, D. 2000. Stable isotope analysis of the origins of zooplankton carbon in lakes of differing trophic state. *Oecologia,* 123**,** 232-240.

Gron, K. & Robson, H. 2016. The Ertebølle Zooarchaeological Dataset from Southern Scandinavia. *Open Quaternary,* 2**,** 1-15.

Grøn, O. 1983. Social behaviour and settlement structure: preliminary results of a distribution analysis on sites of the Maglemose culture. *Journal of Danish Archaeology,* 2**,** 32-42.

Grøn, O. 2003. Mesolithic dwelling places in south Scandinavia: their definition and social interpretation. *Antiquity,* 77**,** 685-708.

Grøn, O. 2015. Territorial Infrastructure, Markers and Tension in Late Mesolithic Hunter-gatherer Societies: An Ethnoarchaeological Approach. *In:* Bicho, N., Detry, C., Price, T. D. & Cunha, E. (eds.) *Muge 150th: The 150th Anniversary of the Discovery of Mesolithic Shellmiddens.* Newcastle: Cambridge Scholars Publishing.

Grøn, O. & Kuznetsov, O. 2000. Ethno-archaeology among Evenkian forest hunters. Preliminary results and a different approach to reality. *In:* Larsson, L., H, K., K, K., D, L. & A, Å. (eds.) *Mesolithic on the Move. Papers presented at the Sixth International Conference on the mesolithic in Europe, Stockholm 2000.* 216-221. Oxford: Oxbow Books.

Grøn, O. & Skaarup, J. 1991. Møllegabet II— A Submerged Mesolithic Site and a "Boat Burial" from Ærø. *Journal of Danish Archaeology,* 10**,** 38-50.

Grøn, O., Turov, M. & Klokkernes, T. 2008. Settling in the landscape–settling the land: Ideological aspects of territoriality in a Siberian hunter-gatherer society. *In:* Olofsson, A. (ed.) *Archaeology of Settlements and Landscapes in the North.***,** Vuollerim Papers on Hunter-Gatherer Archaeology 2. 57-80. Umeå: Umeå University.

Gross, E. 1898. *Die Formen der Familie und die Formen der Wirtschaft,* Paderborg: Salzwasser.

Gummesson, S., Karlsson, J., Kivikero, H., Magnell, O. & Storå, J. Manuscript. *Osteologisk analys av djurbenen från Strandvägen. Arkeologisk undersökning. Östergötlands län, Östergötland, Motala kommun, Motala socken, fastighet Strandvägen 1. RAÄ 290* OFL Rapport 2017:4*,* Osteologiska forskningslaboratoriet Stockholms Universitet.

Gummesson, S. & Molin, F. 2016. The Mesolithic Cemetery at Strandvägen, Motala, in Eastern central Sweden. *In:* Grünberg, J. M., Gramsch, B., Larsson, L., Orschiedt, J. & Meller, H. (eds.) *Mesolithic Burials – Rites, Symbols and Social Organisation of Early Postglacial Communities. International Conference Halle (Saale), Germany, 18th–21st September 2013.***,** 145-159. Halle: Landesmuseum Halle.

Günther, T., Malmström, H., Svensson, E. M., Omrak, A., Sánchez-Quinto, F., Kılınç, G. M., Krzewińska, M., Eriksson, G., Fraser, M., Edlund, H., Munters, A. R., Coutinho, A., Simões, L. G., Vicente, M., Sjölander, A., Jansen Sellevold, B., Jørgensen, R., Claes, P., Shriver, M. D., Valdiosera, C., Netea, M. G., Apel, J., Lidén, K., Skar, B., Storå, J., Götherström, A. & Jakobsson, M. 2018. Population genomics of Mesolithic Scandinavia: Investigating early postglacial migration routes and high-latitude adaptation. *PLoS biology,* 16**,** e2003703.

Gustafsson, B. G. & Westman, P. 2002. On the causes for salinity variations in the Baltic Sea during the last 8500 years. *Paleoceanography,* 17**,** 12:1-12:14.

Gustafsson, J. 2008. Paradis i inland. *Urminne,* 2008/7**,** 7-14.

Habermehl, K. 1961. *Altersbestimmung bei Haustieren, Pelztieren und beim jagdbaren Wild,* Berlin: Paul Parey.

Hagberg, U. E., Beskow-Sjöberg, M. & Boessneck, J. 1977. *The archaeology of Skedemosse,* Stockholm: Almqvist & Wiksell.

Hahn, J. 2000. The gravettian in southwest germany - environment and economy. *In:* Svoboda, J., Roebroeks, W., Mussi, M. & Fennema, K. (eds.) *Hunters of the golden age. The mid Upper Palaeolithic of Eurasia, 30,000-20,000 BP.* 249-256. Leiden: University of Leiden.

Hallgren, F. 2011. Mesolithic skull depositions at Kanaljorden, Motala, Sweden. *Current Swedish Archaeology,* 19**,** 244-246.

Hallgren, F. & Fornander, E. 2016. Skulls on stakes and skulls in water. Mesolithic mortuary rituals at Kanaljorden, Motala, Sweden, 7000 BP. *In:* Grünberg, J. M., Gramsch, B., Larsson, L., Orschiedt, J. & Meller, H. (eds.) *Mesolithic Burials–Rites, Symbols and Social Organisation of Early Postglacial Communities. International Conference Halle (Saale), Germany, 18th-21st September 2013.***,** 161-174. Halle: Landesmuseum Halle.

Halstead, P. & O'Shea, J. M. 1989. Introduction: cultural responses to risk and uncertainty. *In:* O'Shea, J. M. & Halstead, P. (eds.) *Bad year economics: cultural responses to risk and uncertainty.* 1-8. Cambridge: Cambridge University Press.

Hammarstrand Dehman, C. & Sjöström, A. 2009. *Mesolitiska lämningar i Rönneholms mosse. Arkeologisk förundersökning 2008. Hassle 32: 18, Stehag socken, Eslövs kommun, Skåne,* Lund: Institutionen för arkeologi och antikens historia, Lunds universitet,.

Hammond, P., Berggren, P., Benke, H., Borchers, D., Collet, A., Heide-Jørgensen, M., Heimlich, S., Hiby, A., Leopold, M. F. & Øien, N. 2002. Abundance of harbour porpoise and other cetaceans in the North Sea and adjacent waters. *Journal of Applied Ecology,* 39**,** 361-376.

Hanlon, C. & Prahl, G. 1998. *Stenåldersprojekt Ryd: lösfyndsinventering av Almundsryds socken,* Växjö: Smålands museum.

Hansson, A., Landeschi, G., Sjöström, A. & Nilsson, B. Manuscript. Filling the gap: A new Early Holocene shoreline displacement curve for Blekinge, southern Sweden.

Hansson, A., Nilsson, B., Sjöström, A., Björck, S., Holmgren, S., Linderson, H., Magnell, O., Rundgren, M. & Hammarlund, D. 2018. A submerged Mesolithic lagoonal landscape in the Baltic Sea, south-eastern Sweden – Early Holocene environmental reconstruction and shore-level displacement based on a multiproxy approach. *Quaternary International,* 463**,** 110-123.

Härkönen, L., Dietz, R., Reijnders, P., Teilmann, J., Harding, K., Hall, A., Brasseur, S., Siebert, U., Goodman, S. J. & Jepson, P. D. 2006. A review of the 1988 and 2002 phocine distemper virus epidemics in European harbour seals. *Diseases of aquatic organisms,* 68**,** 115-130.

Haughey, F. 2012. Rivers and Lakes. *In:* Menotti, F. & O'Sullivan, A. (eds.) *The Oxford Handbook of Wetland Archaeology.* 385-397. Oxford: Oxford University Press.

Hayden, B. 1995. Pathways to power: Principles for creating socioeconomic inequalities. *In:* Price, T. D. & Feinman, G. M. (eds.) *Foundations of social inequality.* 15-86. New York: Plenum.

Hayden, B., Eldridge, M., Eldridge, A. & Cannon, A. 1985. Complex hunter-gatherers in interior British Columbia. *In:* Price, D. T. & Brown, J. A. (eds.) *Prehistoric hunter-gatherers: The emergence of cultural complexity.* 181-199. New York: Academic Press.

Hedges, R. E. & Reynard, L. M. 2007. Nitrogen isotopes and the trophic level of humans in archaeology. *Journal of Archaeological Science,* 34**,** 1240-1251.

Hedman, S.-D. 2003. *Boplatser och offerplatser: ekonomisk strategi och boplatsmönster bland skogssamer 700-1600 AD,* Umeå: Institutionen för arkeologi och samiska studier, Umeå universitet.

Heinrich, D. 1991. *Untersuchungen an Skelettresten wildlebender Säugetiere aus dem mittelalterlichen Schleswig: Ausgrabung Schild 1971-1975,* Ausgrabungen in Schleswig, Berichte und Studien 9*,* Neumünster: Karl Wachholtz.

Hellgren, F. 2015. *En osteologisk analys av benmaterialet från den mesolitiska kustboplatsen Huseby klev,* Unpublished seminar paper in Historical Osteology*,* Lund: Department of Archaeology and Ancient History, Lund University.

Henriksen, B., Rosenlund, K. & Sørensen, G. 1980. *Lundby-Holmen. Pladser af Maglemose-type i Sydsjælland,* Copenhagen: Det Kongelige Nordiske Oldskriftselskab.

Henriksen, B. B., Aaris-Sørensen, K. & Sørensen, I. 1976. *Sværdborg I: excavations 1943-44: a settlement of the Maglemose culture,* Copenhagen: Akademisk forlag.

Henry, D. O. 1985. Preagricultural sedentism: the Natufian example. *In:* Price, T. D. & Brown, J. A. (eds.) *Prehistoric Hunter-Gatherers: The Emergence of Cultural Complexity.* 365-384. Orlando: Academic Press.

Hernek, R. 1998. Norra området – en mesolitisk boplats med hyddlämning och härdar. *In:* Bengtsson, L., Hernek, R. & Johansson, G. (eds.) *Timmerås och Hällorna/Flykärr-boplatsundersökningar i mellersta Bohuslän. Arkeologiska undersökningar för motorvägen Lerbo-Torp. Del 3.* Kungsbacka: Riksantikvarieämbetet, UV Väst.

Higgs, E. S. & Vita-Finzi, C. 1972. Prehistoric economies: a territorial approach. *In:* Higgs, E. S. (ed.) *Papers in Economic Prehistory.* 27-36. Cambridge: Cambridge University Press.

Hildebrand, H. 1883. Fynden vid ringsjön. *Kongl. vitterherhets historie och antiqvitets akademins månadsblad,* 12**,** 60-72.

Hildebrand, H. 1886. Fynden vid ringsjön. *Kongl. vitterherhets historie och antiqvitets akademins månadsblad,* 16**,** 140-144; 184-186.

Hilton, C. E., Auerbach, B. M. & Cowgill, L. W. 2014. *The foragers of Point Hope: the biology and archaeology of humans on the edge of the Alaskan Arctic,* Cambridge: Cambridge University Press.

Hublin, J.-J., Ben-Ncer, A., Bailey, S. E., Freidline, S. E., Neubauer, S., Skinner, M. M., Bergmann, I., Le Cabec, A., Benazzi, S. & Harvati, K. 2017. New fossils from Jebel Irhoud (Morocco) and the Pan-African origin of Homo sapiens. *Nature,* 546.7657**,** 289-292.

Hudson, M. J. 2014. The Ethnohistory and Anthropology of 'Modern' Hunter-Gatherers. *In:* Cummings, V., Jordan, P. & Zvelebil, M. (eds.) *The Oxford Handbook of the Archaeology and Anthropology of Hunter-Gatherers.* 1054-1070. Oxford: Oxford University Press.

Hultgreen, T., Johansen, O. & Lie, R. 1985. Stiurhelleren i Rana Dokumentasjon av korn, husdyr og sild i yngre steinalder. *Viking,* 48**,** 83-102.

Hussey, N. E., MacNeil, M. A., McMeans, B. C., Olin, J. A., Dudley, S. F., Cliff, G., Wintner, S. P., Fennessy, S. T. & Fisk, A. T. 2014. Rescaling the trophic structure of marine food webs. *Ecology Letters,* 17**,** 239-250.

Ingold, T. 1982. Response to "The Significance of Food Storage among Hunter-Gatherers: Residence Patterns, Population Densities, and Social Inequalities." *Current Anthropology,* 23**,** 531-532.

Ingold, T. 1983. The significance of storage in hunting societies. *Man,* 18**,** 553-571.

Iregren, E. & Lepiksaar, J. 1993. The mesolithic site in Hög in a south Scandinavian perspective—A snap shot from early Kongemose culture. *Zeitschrift für Archäologie,* 27**,** 29-38.

Jackson, A. L., Inger, R., Parnell, A. C. & Bearhop, S. 2011. Comparing isotopic niche widths among and within communities: SIBER–Stable Isotope Bayesian Ellipses in R. *Journal of Animal Ecology,* 80**,** 595-602.

Jansson, P., Larsson, F., Lövgren, A.-K., Rommedahl, H., Knöös, S. & Mårtensson, J. 1998. *Osteologisk analys av den mesolitiska lokalen Ringsjöholm,* Unpublished seminar paper in Historical Osteology*,* Lund: Department of Archaeology and Ancient History, Lund University.

Jenkins, S. G., Partridge, S. T., Stephenson, T. R., Farley, S. D. & Robbins, C. T. 2001. Nitrogen and carbon isotope fractionation between mothers, neonates, and nursing offspring. *Oecologia,* 129**,** 336-341.

Jensen, J. 2001. *Danmarks Oldtid, Stenalderen 13.000-2.000 f. Kr,* København: Gyldendal.

Jochelson, W. Unpublished typescript of MS. The Kamchadals. http://www.facultysite.sinanewt.on-rev.com/JochelsonTheKamchadals.pdf: Accessed Oktober 2015.

Jochim, M. A. 2011. The Mesolithic. *In:* Milisauskas, S. (ed.) *European Prehistory.* 115-142. New York: Springer.

Johansson, G. 2014. *En 10 000 år gammal boplats med organiskt material i Mölndal. Ytterligare en överlagrad Sandarnaboplats vid Balltorp. Västra Götalands län, Västergötland, Mölndal stad, Balltorp 1: 124, Mölndal 182,* Mölndal: Riksantikvarieämbetet, UV Väst.

Johnson, C. N., Bradshaw, C. J., Cooper, A., Gillespie, R. & Brook, B. W. 2013. Rapid megafaunal extinction following human arrival throughout the New World. *Quaternary International,* 308**,** 273-277.

Jones, A. K. 1986. Fish bone survival in the digestive systems of the pig, dog and man: some experiments. *In:* Brinkhuizen, D. C. & Clason, A. T. (eds.) *Fish and Archaeology.* 53-61. Oxford: Archaeopress.

Jones, A. K. 1999. Walking the cod: an investigation into the relative robustness of cod, Gadus morhua, skeletal elements. *Internet Archaeology 7.*

Jonsson, L. 1986. Fish bones in late Mesolithic human graves at Skateholm, Scania, South Sweden. *In:* Brinkhuizen, D. C. & Clason, A. T. (eds.) *Fish and Archaeology. Studies in Osteometry, Taphonomy, Seasonality and Fishing Methods.* 62-79. BAR International Series 294. Oxford: BAR.

Jonsson, L. 1988. The vertebrate faunal remains from the Late Atlantic settlement Skateholm in Scania, South Sweden. *In:* Larsson, L. (ed.) *The Skateholm Project I: Man and Environment.* 56-88. Lund: Almqvist & Wiksell International.

Jonsson, L. 1996. *Fauna och landskap i Göteborgstrakten under boreal tid. Djurbensfynden från den boreala kustboplatsen vid Balltorp, Mölndals kommun, Västergötland,* Kungsbacka: Riksantikvarieämbetet, UV Väst.

Jonsson, L. 2005. Rapport over inledande osteologisk underökning. *In:* Nordqvist, B. (ed.) *Huseby Klev, en kustboplats med bevarat organiskt material från äldsta mesolitikum till järnålder, Bohuslän, Morlanda socken, Huseby 2:4 och 3:13. RAÄ 89, 485.* Mölndal: Riksantikvarieämbetet, UV Väst

Jørgensen, S. 1956. Kongemosen. Endnu en Aamose-Boplads fra Ældre Stenalder. *Kuml,* 1956**,** 23-40.

Jørkov, M. L. S., Heinemeier, J. & Lynnerup, N. 2007. Evaluating bone collagen extraction methods for stable isotope analysis in dietary studies. *Journal of Archaeological Science,* 34**,** 1824-1829.

Kalling, S. 1936. Fynd från stenåldern vid Segebro. *Malmö fornminnesförenings årskrift,* 1936. Malmö.

Karsten, P. 1994. *Att kasta yxan i sjön: en studie över rituell tradition och förändring utifrån skånska neolitiska offerfynd,* Stockholm: Almqvist & Wiksell International.

Karsten, P. & Knarrström, B. 2003. *The Tågerup excavations,* Lund: UV Syd, Avd. för arkeologiska undersökningar, Riksantikvarieämbetet.

Keeley, L. H. 1988. Hunter-gatherer economic complexity and "population pressure": A cross-cultural analysis. *Journal of Anthropological Archaeology,* 7**,** 373-411.

Kelly, R. L. 1983. Hunter-gatherer mobility strategies. *Journal of anthropological research,* 39**,** 277-306.

Kelly, R. L. 1991. Sedentism, sociopolitical inequality, and resource fluctuations. *In:* Gregg, S. (ed.) *Between bands and states: Sedentism, Subsistence and Interaction in Small Scale Societies.* 135-160. Carbondale: Illinois University Press.

Kelly, R. L. 1992. Mobility/sedentism: concepts, archaeological measures, and effects. *Annual Review of Anthropology,* 21**,** 43-66.

Kelly, R. L. 2013. *The lifeways of hunter-gatherers: The foraging spectrum,* Cambridge: Cambridge University Press.

Kent, S. 1989. Cross-cultural perceptions of farmers as hunters and the value of meat. *In:* Kent, S. (ed.) *Farmers as hunters: the implications of sedentism.* 1-17. Cambridge: Cambridge University Press.

Kindgren, H. 1983. Grävningarna vid Hornborgasjön. *Västergötlands fornminnesförenings tidskrift,* 1983-1984**,** 197-210.

Kindgren, H. 1995. Hensbacka-Hogen-Hornborgasjön: Early Mesolithic coastal and inland settlements in western Sweden. *In:* Fischer, A. (ed.) *Man & Sea in the Mesolithic.* 171-184. Oxbow Monograph 53. Oxford: Oxbow.

King, T. F. 1978. Don't that beat the band? Non-egalitarian political organization in prehistoric central California. *In:* Redman, C. L. (ed.) *Social archaeology: Beyond subsistence and dating.* 225-248. New York: Academic Press.

Kini, U. & Nandeesh, B. 2012. Physiology of bone formation, remodeling, and metabolism. *In:* Fogelman, I., Gnanasegaran, G. & van der Wall, H. (eds.) *Radionuclide and hybrid bone imaging.* 29-57. Berlin: Springer.

Kjällquist, M. 2001. Gåvor eller avfall. En studie av sex mesolitiska gravar från Tågerup. *In:* Karsten, P. & Knarrström, B. (eds.) *Tågerup specialstudier.* 32-69. Lund: UV Syd, Avd. för arkeologiska undersökningar.

Kjällquist, M., Boethius, A. & Emilsson, A. 2016. *Norje Sunnansund. Boplatslämningar från tidigmesolitikum och järnålder. Särskild arkeologisk undersökning 2011 och arkeologisk förundersökning 2011 och 2012, Ysane socken, Sölvesborgs kommun i Blekinge län,* Karlskrona: Blekinge museum.

Kjällquist, M. & Friman, B. 2017. *Ljungaviken etapp 2, yta A. Ett överlagrat boplatsområde från mellanmesolitikum. Rapport 2017:99 Arkeologisk undersökning 2016 Blekinge, Sölvesborgs kommun, Sölvesborgs socken, Sölve 3:10,* Lund: Arkeologerna, Statens historiska museer.

Kjällquist, M. & Price, T. D. Manuscript. Isotopic Proveniencing of Mesolithic Human Remains from Norje Sunnansund, Sweden.

Kjellmark, K. 1904. Öfversikt af Sveriges stenåldersboplatser. *Ymer,* 24**,** 187-225.

Kjellmark, K. B. 1903. *En stenåldersboplats i Järavallen vid Limhamn,* Stockholm: Uppsala Universitet.

Kleanthidis, P., Sinis, A. & Stergiou, K. 1999. Length-weight relationships of freshwater fishes in Greece. *Naga, The ICLARM Quarterly,* 22**,** 37-40.

Knape, A. & Ericson, P. 1983. Återupptäckta fynd från grottan Stora Förvar: ett preliminärt meddelande. *Fornvännen,* 78**,** 169-175.

Koutrakis, E. & Tsikliras, A. 2003. Short Communication. Length-weight relationships of fishes from three northern Aegean estuarine systems (Greece). *Journal of Applied Ichthyology,* 19**,** 258-260.

Kullander, S., Nyman, L., Jilg, K. & Delling, B. 2012. *Ryggsträngsdjur. Strålfeniga fiskar. Chordata: Actinopterygii. ,* Nationalnyckeln till Sveriges flora och fauna*,* Uppsala: SLU.

Kurck, A. 1872. Om stenålderns delning och kustfynd i Skåne. *Samlingar till Skånes historia, fornkunskap och beskrifning,* 1872**,** 1-41.

Lantis, M. 1984. Aleut. *In:* Damas, D. (ed.) *Handbook of North American Indians. Vol. 5, Arctic.* 161-184. Washington, DC: Smithsonian Institution Press.

Larsen, H. & Rainey, F. 1948. *Ipiutak and the Arctic whale hunting culture,* Anthropological Paper 42*,* New York: American Museum of Natural History.

Larsson, L. 1975. A Contribution to the Knowledge of Mesolithic Huts in Southern Scandinavia. *Meddelanden från Lunds universitets historiska museum,* 1973-1974**,** 5-28.

Larsson, L. 1978a. *Ageröd l:B - Ageröd l:D: a study of early Atlantic settlement in Scania,* Acta Archaeological Lundensia Series in 4°, 12*,* Lund: Lund university.

Larsson, L. 1978b. Mesolithic antler and bone artefacts from Central Scania. *Meddelanden från Lunds universitets historiska museum,* 1977-1978**,** 28-67.

Larsson, L. 1980. Some aspects of the Kongemose culture of Southern Sweden. *Meddelanden från Lunds univesitets historiska museum,* 1979-80**,** 5-22.

Larsson, L. 1982. *Segebro: en tidigatlantisk boplats vid Sege ås mynning,* Malmö: Malmö museum.

Larsson, L. 1983. *Ageröd V: An Atlantic bog site in central Scania,* Lund: Institute of Archaeology, University of Lund

Larsson, L. 1988a. *Ett fångstsamhälle för 7000 år sedan: boplatser och gravar i Skateholm,* Lund: Signum.

Larsson, L. (ed.) 1988b. *The Skateholm Project I: Man and Environment,* Lund: Almqvist & Wiksell International.

Larsson, L. 1989. Late Mesolithic settlements and cemeteries at Skateholm, southern Sweden. *In:* Bonsall, C. (ed.) *The Mesolithic in Europe.* 367-378. Edinburgh: John Donald.

Larsson, L. 1993. The Skateholm Project: late Mesolithic coastal settlement in southern Sweden. *In:* Bogucki, P. (ed.) *Case studies in European prehistory.* 31-62. Boca Raton: CRC.

Larsson, L. 2007. Wetland and Ritual Deposits during the Neolithic. A Local Study in a Micro-environment of a Macro-phenomenon. *Lund Archaeological Review,* vol. 11-12, 2005-2006**,** 59-69.

Larsson, L., Meiklejohn, C. & Newell, R. R. 1981. Human skeletal material from the Mesolithic site of Ageröd I: HC, Scania, Southern Sweden. *Fornvännen,* 76**,** 161-167.

Layton, R. & Rowley-Conwy, P. 2013. Wild things in the north? Hunter-gatherers and the tyranny of the colonial perspective. *Anthropologie,* 51**,** 213-230.

Leduc, C. 2012. Ungulates exploitation for subsistence and raw material, during the Maglemose culture in Denmark: the example of Mullerup site (Sarauw's Island) in Sjælland. *Danish Journal of Archaeology,* 1**,** 62-81.

Leduc, C. 2014. A specialized Early Maglemosian site at Lundby Mose (Zealand, Denmark): a contribution to the understanding of Maglemosian patterns of animal resource exploitation. *Journal of Archaeological Science,* 41**,** 199-213.

Lee, R. B. & DeVore, I. (eds.) 1968. *Man the hunter,* Chicago: Aldine.

Lemppenau, U. 1964. *Geschlechts-und Gattungsunterschiede am Becken mitteleuropäischer Wiederkäuer,* München: Ludwig Maximilians Universität.

Lepiksaar, J. 1972. Zoologisk rapport. *In:* Kaelas, L., Hubendick, B. & Eriksson, G. (eds.) *Stenåldersboplatsen Bua Västergård. Rapporter över arkeologisk, zoologisk och geologisk undersökning. Etapp 1.* Göteborg: Göteborgs universitet.

Lepiksaar, J. 1978. Bone remains from the mesolithic settlements Ageröd I:B and Ageröd I:D. *In:* Larsson, L. (ed.) *Ageröd I:B – Ageröd I:D, a study of early atlantic settlement in Scania.* 234-244. Lund: Lund university.

Lepiksaar, J. 1982. Djurrester från den tidigatlantiska boplatsen vid Segebro nära Malmö i Skåne (Sydsverige). *In:* Larsson, L. (ed.) *Segebro: En tidigatlantisk boplats vid Sege ås mynning.* 105-128. Malmö: Malmö museum.

Lepiksaar, J. 1983a. Animal remains from the atlantic bog site at Ageröd V in central Scania. *In:* Larsson, L. (ed.) *Ageröd V: An Atlantic bog site in central Scania.* 159-168. Lund: Institute of Archaeology, University of Lund.

Lepiksaar, J. 1983b. Zoologisk undersökning. *In:* Wigfors, J., Kaelas, L. & Andersson, S. (eds.) *Bua Västergård – en 8000 år gammal kustboplats.* 115-161. Göteborg: Göteborgs arkeologiska museum.

Lepiksaar, J. 1994. *Introduction to osteology of fishes for paleozoologists,* Göteborg: Unpublished manuscript.

Lepiksaar, J. 2001. *Die spät-und postglaziale Faunengeschichte der Süsswasserfische Schwedens: Übersicht der subfossilen Funde und der Versuch einer faunengeschichtlichen Analyse der rezenten Artareale,* Kiel: Oetker-Voges.

Lepiksaar, J., Heinrich, D. & Radtke, C. 1977. Untersuchungen an Fischresten aus der frühmittelalterlichen Siedlung Haithabu. *Behrichte über die Ausgrabungen in Haithabu 10.* Neumünster: Karl Wachholtz.

Lidén, K. 1995. *Prehistoric diet transitions: an archaeological perspective,* Stockholm: Archaeological Research Laboratory, Stockholm University.

Lidén, K. 1996. A dietary perspective on Swedish hunter-gatherer and Neolithic populations. *Laborativ Arkeologi,* 9**,** 5-23.

Lidén, K., Eriksson, G., Nordqvist, B., Götherström, A. & Bendixen, E. 2004. "The wet and the wild followed by the dry and the tame"–or did they occur at the same time? Diet in Mesolithic–Neolithic southern Sweden. *Antiquity,* 78**,** 23-33.

Liljegren, R. 1982. *Paleoekologi och strandförskjutning i en Littorinavik [vid Spjälkö] i mellersta Blekinge: a contribution to IGCP project 61 (sea level changes),* Lund: Department of Quaternary Geology, Lund University.

Lima-Ribeiro, M. S. 2013. Insistence on narrative reviews or preference for overkill hypothesis? Re-analyses show no evidence against Lima-Ribeiro & Diniz-Filho's conclusions. *Quaternary International,* 308**,** 278-281.

Lima-Ribeiro, M. S. & Diniz-Filho, J. A. F. 2013. American megafaunal extinctions and human arrival: improved evaluation using a meta-analytical approach. *Quaternary International,* 299**,** 38-52.

Lindqvist, C. & Possnert, G. 1997. The subsistence economy and diet at Jakobs/Ajvide and Stora Förvar, Eksta Parish and other Prehistoric Dwelling and burial sites on Gotland in long term Perspective. *In:* Burenhult, G. (ed.) *Remote sensing vol 1: applied techniques for the study of cultural resources and the localization, identification and documentation of sub-surface prehistoric remains in Swedish archaeology.* 29-90. Stockholm: Department of Archaeology, University of Stockholm.

Lindqvist, C. & Possnert, G. 1999. The first seal hunter families on Gotland. On the Mesolithic occupation in the Stora Förvar cave. *Current Swedish Archaeology,* 7**,** 65-87.

Longin, R. 1971. New method of collagen extraction for radiocarbon dating. *Nature,* 230**,** 241-242.

Lõugas, L. 2017. Mesolithic hunting and fishing in the coastal and terrestrial environments of the eastern Baltic. *In:* Umberto, A., Rizzetto, M., Russ, H., Vickers, K. & Viner-Daniels, S. (eds.) *The Oxford Handbook of Zooarchaeology.* 52-68. Oxford: Oxford University Press.

Lubinski, P. 1996. Fish heads, fish heads: an experiment on differential bone preservation in a salmonid fish. *Journal of Archaeological Science,* 23**,** 175-181.

Lundmark, L. 1982. *Uppbörd, utarmning, utveckling: det samiska fångstsamhällets övergång till rennomadism i Lule lappmark,* Lund: Arkiv för studier i arbetarrörelsens historia.

Lyman, R. L. 1991. *Prehistory of the Oregon Coast,* San Diego: Academic Press.

Lyman, R. L. 1994. *Vertebrate taphonomy,* Cambridge: Cambridge University Press.

Lyman, R. L. 2008. *Quantitative paleozoology,* Cambridge: Cambridge University Press.

Madsen, A. P., Müller, S., Neergaard, C., Petersen, C. J., Rostrup, E., Steenstrup, K. J. V. & Winge, H. 1900. *Affaldsdynger fra stenalderen i Danmark: undersøgte for Nationalmuseet,* Paris: AA Hachette.

Magnell, O. 2006. *Tracking wild boar and hunters: osteology of wild boar in Mesolithic South Scandinavia,* Acta Archaeologica Lundensia Series in 8°, vol. 51. Studies in Osteology 1*,* Lund: Almqvist & Wiksell International.

Magnell, O. 2010. Djurben från Rönneholms mosse–osteologisk analys av material från utgrävningar 2008-2009. *Reports in osteology 2010: 8.* Lund: Department of Archaeology and Ancient History, Lund University

Magnell, O. 2011. Djurben från Rönneholms mosse–osteologisk analys av material från utgrävningar 2010. Reports in osteology 2011:7. Lund: Department of Archaeology and Ancient History, Lund University.

Magnell, O. 2017. Climate Change at the Holocene Thermal Maximum and Its Impact on Wild Game Populations in South Scandinavia. *In:* Monks, G. (ed.) *Climate Change and Human Responses. A Zooarchaeological Perspective.* 123-135. Dordrecht: Springer.

Magnell, O. Submitted-a. Hunters in Their Environment. Mesolithic Hunting in Relation to a Changing Environment and Its Affect on Wild Game Populations in South Scandinavia. *MESO 2010. Proceedings of the Eight International Conference on the Mesolithic in Europe, Santander 13th-17th September, 2010.* Unpublished paper.

Magnell, O. Submitted-b. The seasonality of hunting during the Mesolithic in south Scandinavia. *In:* Boric, D. (ed.) *MESO 2015. Proceedings of the ninth International Conference on the Mesolithic in Europe, Belgrade.* Unpublished paper.

Malainey, M. E. 2011. *A consumer's guide to archaeological science: analytical techniques,* Manuals in Archaeological Method, Theory and Technique*,* New York: Springer.

Mannermaa, K., Panteleyev, A. & Sablin, M. 2008. Birds in Late Mesolithic burials at Yuzhniy Oleniy ostrov (Lake Onega, western Russia) — What do they tell about humans and environment? *Fennoscandia archaeologica,* 25**,** 3-25.

Marlowe, F. W. 2005. Hunter-gatherers and human evolution. *Evolutionary Anthropology,* 14**,** 54-67.

Mårtensson, J. 2001. Mesolitiskt trä. *In:* Karsten, P. & Knarrström, B. (eds.) *Tågerup specialstudier.* 280-301. Lund: UV Syd, Avd. för arkeologiska undersökningar.

Matson, R. G. 1992. The evolution of Northwest Coast subsistence. *Research in Economic Anthropology Supplement,* 6**,** 367-428.

Matsui, A. 1996. Archaeological investigations of anadromous salmonid fishing in Japan. *World Archaeology,* 27**,** 444-460.

Mayer, J. J. & Brisbin, I. L. 1988. Sex identification of Sus scrofa based on canine morphology. *Journal of Mammalogy,* 69**,** 408-412.

McComb, A. M. & Simpson, D. 1999. The wild bunch: exploitation of the hazel in prehistoric Ireland. *Ulster Journal of Archaeology,* 58**,** 1-16.

McCutchan, J. H., Lewis, W. M., Kendall, C. & McGrath, C. C. 2003. Variation in trophic shift for stable isotope ratios of carbon, nitrogen, and sulfur. *Oikos,* 102**,** 378-390.

McKechnie, I. 2005. *Five thousand years of fishing at a shell midden in the Broken Group Islands, Barkley Sound, British Columbia,* Burnaby: Department of Archaeology, Simon Fraser University.

McKechnie, I. 2007. Investigating the complexities of sustainable fishing at a prehistoric village on western Vancouver Island, British Columbia, Canada. *Journal for Nature Conservation,* 15**,** 208-222.

McKechnie, I. 2012. Zooarchaeological Analysis of the Indigenous Fishery at the Huu7ii Big House and Back Terrace, Huu-ay-aht Territory, Southwestern Vancouver Island. *In:* McMillan, A. & St. Claire, D. (eds.) *Huu7ii: Household Archaeology at a Nuu-chah-nulth Village Site in Barkley Sound.* 154-186. Burnaby, BC: Archaeology Press, Simon Fraser University.

McKechnie, I. & Moss, M. L. 2016. Meta-analysis in zooarchaeology expands perspectives on Indigenous fisheries of the Northwest Coast of North America. *Journal of Archaeological Science: Reports,* 8**,** 470-485.

McMillan, A. D., McKechnie, I., St. Claire, D. E. & Frederick, S. G. 2008. Exploring variability in maritime resource use on the Northwest Coast: a case study from Barkley Sound, western Vancouver Island. *Canadian Journal of Archaeology/Journal Canadien d'Archéologie,* 32**,** 214-238.

Medlock, R. C. 1975. Faunal analysis. *In:* Schiffer, M. B. & House, J. H. (eds.) *The Cache River archaeological project: an experiment in contract archaeology.* 223-242. Arkansas Archaeological Survey Research Series No. 8. Fayetteville: Arkansas Archaeological Survey.

Mellars, P. A. 1985. The ecological basis of social complexity in the Upper Paleolithic of southwestern France. *In:* Price, T. D. & Brown, J. A. (eds.) *Prehistoric hunter-gatherers: The emergence of cultural complexity.* 271-297. Orlando: Academic Press.

Miettinen, A., Sarmaja-Korjonen, K., Sonninen, E., Jungner, H., Lempiäinen, T., Ylikoski, K., Mäkiaho, J. & Carpelan, C. 2008. The Palaeoenvironment of the'Antrea Net Find'. *Iskos,* 16**,** 71-87.

Minagawa, M. & Wada, E. 1984. Stepwise enrichment of 15N along food chains: further evidence and the relation between δ15N and animal age. *Geochimica et cosmochimica acta,* 48**,** 1135-1140.

Mithen, S. 1987. Prehistoric red deer hunting strategies: a cost-risk benefit analysis with reference to upper Palaeolithic Northern Spain and Mesolithic Denmark. *In:* Rowley-Conwy, P., Zvelebil, M. & Blankholm, H. P. (eds.) *Mesolithic Northwest Europe: recent trends.* 93-108. Sheffield: University of Sheffield.

Mithen, S. J. 1990. *Thoughtful foragers: a study of prehistoric decision making,* Cambridge: Cambridge University Press.

Mittnik, A., Wang, C.-C., Pfrengle, S., Daubaras, M., Zariņa, G., Hallgren, F., Allmäe, R., Khartanovich, V., Moiseyev, V., Tõrv, M., Furtwängler, A., Andrades Valtueña, A., Feldman, M., Economou, C., Oinonen, M., Vasks, A., Balanovska, E., Reich, D., Jankauskas, R., Haak, W., Schiffels, S. & Krause, J. 2018. The genetic prehistory of the Baltic Sea region. *Nature Communications,* 9**,** 1-11.

Møhl, U. 1961. Sammenfatning af knoglematerialet. In Verupbopladsen en maglemoseboplads i Åmosen. *Aarbøger for Nordisk Oldkyndighed og Historie,* 1961**,** 132-136.

Møhl, U. 1978. Elsdyrskeletterne fra Skottemarke og Favrbo; Skik og brug ved borealtidens jagter. *Aarbøger For Nordisk Oldkyndighed og Historie,* 1978**,** 5-32.

Møhl, U. 1979. Faunaen omkring Flaadet-bopladsen en boreal bosættelse på Langeland. *In:* Skaarup, J. (ed.) *Flaadet En tidig Maglemoseboplads på Langeland.* 136-145. Rudkøbing: Langelands Museum.

Møhl, U. 1984. Dyreknogler fra nogle af borealtidens senere bopladser i den sjællandske Aamose. *Aarbøger for Nordisk oldkyndlighed og historia,* 1984**,** 47-60.

Møhl, U. 1987. Faunalevn fra Argusgrunden: En undersøisk boplads fra tidlig Atlantisk tid. *In:* Fischer, A., Møhl, U., Bennike, P., Tauber, H., Malmros, C., Scheu Hansen, J. & Smed, P. (eds.) *Argus-grunden - En Undersøisk Boplads fra Jægerstenalderen.* 59-90. Copenhagen: Skov og Naturstyrelsen.

Molin, F., Hagberg, L. & Westermark, A. 2017. Living by the shore: Mesolithic dwellings and household in Motala, eastern central Sweden, 5600–5000calBC. *Journal of Archaeological Science: Reports,* http://dx.doi.org/10.1016/j.jasrep.2017.10.022.

Møller Hansen, K. 2000. Elgjægere–Jagt og kult for 12.000 år siden. *Kulturhistoriske studier. Sydsjællands Museum,* 2000**,** 7-21.

Møller Hansen, K. 2003. Pre-Boreal elk bones from Lundby Mose. I Larsson, Kindgren, Knutsson, Loeffler och Åkerlund red. *In:* Larsson, L., H, K., K, K., D, L. & A, Å. (eds.) *Mesolithic on the Move: Papers Presented at the Sixth International Conference on the Mesolithic in Europe, Stockholm 2000.* Oxford: Oxbow Books.

Møller Hansen, K., Petersen, E. B. & Aaris-Sørensen, K. 2004. Filling the gap: early preboreal Maglemose elk deposits at Lundby, Sjælland, Denmark. *In:* Terberger, T. & Eriksen, B. V. (eds.) *Hunters in a Changing World: Environment and Archaeology of the Pleistocene-Holocene Transition (ca. 11000-9000 BC) in Northern Central Europe; Workshop of the UISPP-Commission XXXII at Greifswald in September 2002.* 75-84. Leidorf: Rahden/Westf.

Monks, G. G. 2006. The Fauna from Ma'acoah (DfSi-5), Vancouver Island, British Columbia: An Interpretive Summary. *Canadian Journal of Archaeology/Journal Canadien d'Archéologie,* 30**,** 272-301.

Moorrees, C. F., Fanning, E. A. & Hunt Jr, E. E. 1963. Age variation of formation stages for ten permanent teeth. *Journal of dental research,* 42**,** 1490-1502.

Morales, A. & Rosenlund, K. 1979. *Fish Bone Measurements: An attempt to standardize the measuring of fish bones from archaeological sites,* Copenhagen: Steenstrupia.

Mulk, I.-M. 1994. *Sirkas - ett samiskt fångstsamhälle i förändring Kr. f. -1600 e. Kr,* Umeå: Institutionen för arkeologi och samiska studier, Umeå universitet.

Munthe, H. & Hansson, H. 1930. En ny boplats från äldre stenåldern på Gotland. *Fornvännen,* 1930**,** 257-85.

Murdoch, J. 1892. *Ethnological results of the Point Barrow expedition,* Ninth Annual Report of the Bureau of Ethnology, 1887-8*.,* Washington, DC: Smithsonian Institution.

Murdock, G. P. 1968. The current status of the world's hunting and gathering peoples. *In:* Lee, R. & DeVore, I. (eds.) *Man the Hunter.* 13-20. Chicago: Aldine.

Nemecek, M. 2015. *Ett Skiftade Mesolitikum En analys av artsammansättningen av klövvilt på nordiska boplatser under mesolitikum,* Unpublished seminar paper in Historical Osteology*,* Lund: Department of Archaeology and Ancient History, Lund University.

Nenadic, O. & Greenacre, M. 2007. Correspondence analysis in R, with two-and three-dimensional graphics: the ca package. *Journal of Statistical Software,* Vol. 20**,** 1-13.

Neophytou, C. 1993. Ecological study of the perch (Perca fluviatilis) in Doirani lake. *Greek Geotech. Sci. Iss.,* 4**,** 38-47.

Newell, R. R., Constandse-Westermann, T. S. & Meiklejohn, C. 1979. The skeletal remains of Mesolithic man in Western Europe: an evaluative catalogue. *Journal of Human Evolution,* 8**,** 1-233.

Nicholson, R. 1993. An investigation into the effects on fish bone of passage through the human gut: some experiments and comparisons with archaeological material. *Circaea,* 10**,** 38-51.

Nicholson, R. A. 1992. Bone survival: The effects of sedimentary abrasion and trampling on fresh and cooked bone. *International Journal of Osteoarchaeology,* 2**,** 79-90.

Nicholson, R. A. 1996. Bone degradation, burial medium and species representation: debunking the myths, an experiment-based approach. *Journal of Archaeological Science,* 23**,** 513-533.

Nielsen, H. N. 1921. Fund i Sværborg og Mullerup moser af skeletdele af mennesker fra den ældste stenalder. *Aarbøger for Nordisk Oldkyndighed og Historie,* 1921**,** 205-218.

Nihlén, J. 1927. *Gotlands stenåldersboplatser,* Stockholm: Kungliga Vitterhets Historie och Antikvitets Akademiens handlingar.

Nilsson, B. & Hanlon, C. 2006. Life and Work During 5.000 Years. *In:* Karsten, P. & Nilsson, B. (eds.) *In the Wake of a Woman. Stone Age Pioneering of North-eastern Scania, Sweden, 10,000-5000 BC. The Årup Settlements.* Stockholm: Riksantikvarieämbetet.

Nilsson, B., Sjöström, A. & Persson, P. 2018. Seascapes of Stability and Change: The Archaeological and Ecological Potential of Early Mesolithic Seascapes, with Examples from Haväng in the South-Eastern Baltic, Sweden. *In:* Persson, P., Skar, B., Breivik, H. M., Riede, F. & Jonsson, L. (eds.) *The Ecology of Early Settlement in Northern Europe - Conditions for Subsistence and Survival.* Sheffield: Equinox.

Nilsson, S. 1866. *Skandinaviska nordens ur-invånare: ett forsök i komparativa ethnografien och ett bidrag till menniskoslägtets utvecklings-historia,* Stockholm: Norstedt.

Noe-Nygaard, N. 1983. The importance of aquatic resources to Mesolithic man at inland sites in Denmark. *In:* Grigson, C. & Clutton-Brock, J. (eds.) *Animals and Archaeology: Shell Middens, Fishes and Birds.* BAR International Series 183. 125-142. Oford: BAR.

Noe-Nygaard, N. 1988. 13C-values of dog bones reveal the nature of changes in man's food resources at the mesolithic-neolithic transition, Denmark. *Chemical Geology: Isotope Geoscience section,* 73**,** 87-96.

Noe-Nygaard, N. 1995. *Ecological, sedimentary and geochemical evolution of the late-glacial to postglacial Åmose lacustrin bay, Denmark,* Fossils and Strata*,* Copenhagen: Scandinavian University Press.

Noe-Nygaard, N., Price, T. D. & Hede, S. U. 2005. Diet of aurochs and early cattle in southern Scandinavia: evidence from 15 N and 13 C stable isotopes. *Journal of Archaeological Science,* 32**,** 855-871.

Noe-Nygaard, N. & Richter, J. 1991. Seventeen Wild Boar Mandibles from Sludegård Sømose-Offal or Sacrifice? *In:* Robinson, D. E. (ed.) *Experimentation and reconstiuction in environmental archaeology. Symposia of the Associationfor Environmental Archaeology N o. 9.* 175-187. Oxford: Oxbow Books.

Nordqvist, B. 2005. *Husby klev: en kustboplats med bevarat organiskt material från äldsta mesoliticum till järnålder: Bohuslän, Morlanda socken, Huseby 2: 4 och 3: 13, RAÄ 89 och 485: arkeologisk förundersökning och undersökning,* Mölndal: Riksantikvarieämbetet, UV Väst

Northridge, S. P., Tasker, M. L., Webb, A. & Williams, J. M. 1995. Distribution and relative abundance of harbour porpoises (Phocoena phocoena L.), white-beaked dolphins (Lagenorhynchus albirostris Gray), and minke whales (Balaenoptera acutorostrata Lacepède) around the British Isles. *ICES Journal of Marine Science,* 52**,** 55-66.

O'Connell, T., Kneale, C., Tasevska, N. & Kuhnle, G. 2012. The diet-body offset in human nitrogen isotopic values: A controlled dietary study. *American journal of physical anthropology,* 149**,** 426-434.

O'Connor, T. 1982. *Animal bones from Flaxengate, Lincoln, c 870-1500,* Archaeology of Lincoln*,* London: Lincoln Archaeological Trust.

O'Shea, J. 1981. Coping with scarcity: exchange and social storage. *Economic archaeology: towards an integration of ecological and social approaches,* 96**,** 167-83.

Ogburn, W. F. 1964. *On culture and social change: selected papers,* Chicago: Chicago Univ. Press.

Okasha, S. 2016. *Philosophy of Science: Very Short Introduction,* Oxford: Oxford University Press.

Olson, C. 2008. *Neolithic Fisheries: osteoarchaeology of fish remains in the Baltic Sea region,* Archaeology and Ancient Culture*,* Stockholm: Stockholm University.

Ōnishi, H. 2014. The Formation of the Ainu Cultural Landscape: Landscape Shift in a Hunter-Gatherer Society in the Northern Part of the Japanese Archipelago. *Journal of world prehistory,* 27**,** 277-293.

Orton, D. C. 2012. Taphonomy and interpretation: An analytical framework for social zooarchaeology. *International Journal of Osteoarchaeology,* 22**,** 320-337.

Österholm, I. 1989. *Bosättningsmönstret på Gotland under stenåldern: en analys av fysisk miljö, ekonomi och social struktur,* Theses and Papers in Archaeology 3*,* Stockholm: Stockholms universitet.

Pagoldh, M. 1995. *Arkeologisk delundersökning av en ca 9000 år gammal stenåldersboplats i Anderstorp, Småland,* Arkeologisk rapport 1995:15*,* Jönköping: Jönköpings läns museum.

Pälsi, S. 1920. Ein steinzeitlicher Moorfund bei Korpilahti im Kirchspiel Antrea, Län Viborg (XXVIII). *Suomen muinaismuistoyhdistyksen aikakauskirja,* 2**,** 3-22.

Parnell, A. C., Inger, R., Bearhop, S. & Jackson, A. L. 2010. Source partitioning using stable isotopes: coping with too much variation. *PloS one,* 5.3**,** e9672.

Parrish, C. R., Holmes, E. C., Morens, D. M., Park, E.-C., Burke, D. S., Calisher, C. H., Laughlin, C. A., Saif, L. J. & Daszak, P. 2008. Cross-species virus transmission and the emergence of new epidemic diseases. *Microbiology and Molecular Biology Reviews,* 72**,** 457-470.

Påsse, T. & Andersson, L. 2005. Shore-level displacement in Fennoscandia calculated from empirical data. *GFF,* 127**,** 253-268.

Payne, S. 1972. Partial recovery and sample bias: the results of some sieving experiments. *In:* Higgs, E. (ed.) *Papers in Economic Prehistory.* 49-64. Cambridge: Cambridge University Press.

Pedersen, K., Peterson, N., Skjutare, M. & Svensson, R. 2005. *Lite mer kött på benen. Jakt, fiske och tillvaratagande vid den mesolitiska lokalen Ringsjöholm,* Unpublished seminar paper in Historical Osteology, Lund: Department of Archaeology and Ancient History, Lund University.

Persson, C. 2012. *Den hemliga sjön–en resa till det småländska inlandet för 9 000 år sedan,* Gothenburg: Gothenburg University.

Philippsen, B. 2012. *Variability in freshwater reservoir effects. Implications for radiocarbon dating of pottery and organisms from estuarine environments,* Aarhus: Aarhus University.

Philippsen, B. 2013. The freshwater reservoir effect in radiocarbon dating. *Heritage Science,* 1**,** 1-19.

Pickard, C. & Bonsall, C. 2004. Deep-sea fishing in the European Mesolithic: fact or fantasy? *European Journal of Archaeology,* 7**,** 273-290.

Pira, A. 1926. On Bone Deposits in the Cave Stora Förvar on the Isle of Stora Karlsö, Sweden. *Acta Zoologica,* 7**,** 123-217.

Pomeroy, P., Twiss, S. & Redman, P. 2000. Philopatry, site fidelity and local kin associations within grey seal breeding colonies. *Ethology,* 106**,** 899-919.

Popper, K. 1963. *Conjectures and refutations: The growth of scientific knowledge,* London: Routledge.

Post, D. M. 2002. Using stable isotopes to estimate trophic position: models, methods, and assumptions. *Ecology,* 83**,** 703-718.

Price, T. D. 1985. Affluent foragers of Mesolithic southern Scandinavia. *In:* Price, T. D. & Brown, J. A. (eds.) *Prehistoric hunter-gatherers: the emergence of cultural complexity.* 341-364. Orlando: Academic Press.

Price, T. D. & Brown, J. A. 1985a. Aspects of Hunter-Gatherer Complexity. *In:* Price, T. D. & Brown, J. A. (eds.) *Prehistoric Hunter-Gatherers: The Emergence of Cultural Complexity.* 3-20. Orlando: Academic Press.

Price, T. D. & Brown, J. A. (eds.) 1985b. *Prehistoric Hunter-Gatherers: The Emergence of Cultural Complexity,* Orlando: Academic Press.

Price, T. D. & Jacobs, K. 1990. Olenii Ostrov: first radiocarbon dates from a major Mesolithic cemetery in Karelia, USSR. *Antiquity,* 64**,** 849-853.

R Core Team 2016. *R: A Language and Environment for Statistical Computing,* Vienna: R Foundation for Statistical Computing.

Radu, V. 2005. *Atlas for the identification of bony fish bones from archaeological sites,* Asociatia Românã de Archeologie. Studii de Preistorie. Supplementum 1*,* Bucarest: Editura Contrast.

Rafferty, J. E. 1985. The archaeological record on sedentariness: recognition, development, and implications. *Advances in archaeological method and theory,* 8**,** 113-156.

Ramsey, C. B., Higham, T., Bowles, A. & Hedges, R. 2004. Improvements to the pretreatment of bone at Oxford. *Radiocarbon,* 46**,** 155-164.

Reed, C. A. 1977. A model for the origin of agriculture in the Near East. *In:* Reed, C. A. (ed.) *Origins of agriculture.* 543-567. The Hague: Mouton.

Reventlow, C. D. 1886. Fynden från Ringsjön. *Kongliga vitterherhets historie och antiqvitets akademins månadsblad,* 1886**,** 140-144.

Reventlow, C. D. 1889. Fynden från Ringsjön. *Kongl. vitterherhets historie och antiqvitets akademins månadsblad,* 1889**,** 77-96.

Reventlow, C. D. 1905. Ringsjöfynden. *Ymer,* 1905**,** 156-172.

Rice, G. E. 1975. *A Systematic Explanation of a Change in Mogollon Settlement Patterns,* Unpublished PhD thesis. Seattle: Department of Anthropology, University of Washington.

Richards, M. P. & Hedges, R. E. 1999. Stable isotope evidence for similarities in the types of marine foods used by Late Mesolithic humans at sites along the Atlantic coast of Europe. *Journal of Archaeological Science,* 26**,** 717-722.

Richards, M. P., Pettitt, P. B., Stiner, M. C. & Trinkaus, E. 2001. Stable isotope evidence for increasing dietary breadth in the European mid-Upper Paleolithic. *Proceedings of the National Academy of Sciences,* 98**,** 6528-6532.

Richter, D., Grün, R., Joannes-Boyau, R., Steele, T. E., Amani, F., Rué, M., Fernandes, P., Raynal, J.-P., Geraads, D., Ben-Ncer, A., Hublin, J.-J. & McPherron, S. P. 2017. The age of the hominin fossils from Jebel Irhoud, Morocco, and the origins of the Middle Stone Age. *Nature,* 546**,** 293-296.

Richter, J. 1982. Adult and juvenile aurochs, Bos primigenius Boj. from the maglemosian site of ulkestrup lyng Øst, Denmark. *Journal of Archaeological Science,* 9**,** 247-259.

Ringrose, T. J. 1993. Bone counts and statistics: a critique. *Journal of Archaeological Science,* 20**,** 121-157.

Ritchie, K., Hufthammer, A. K. & Bergsvik, K. A. 2016. Fjord fishing in Mesolithic Western Norway. *Environmental Archaeology,* 21**,** 309-316.

Ritchie, K. C. 2010. *The Ertebølle Fisheries of Denmark, 5400-4000 BC,* Unpublished PhD thesis. Madison: University of Wisconsin.

Ritchie, K. C., Gron, K. J. & Price, T. D. 2013. Flexibility and diversity in subsistence during the late Mesolithic: Faunal evidence from Asnæs Havnemark. *Danish Journal of Archaeology,* 2**,** 45-64.

Robson, H., Andersen, S., Craig, O., Fischer, A., Glykou, A., Hartz, S., Lübke, H., Schmölcke, U. & Heron, C. 2012. Carbon and nitrogen isotope signals in eel bone collagen from Mesolithic and Neolithic sites in northern Europe. *Journal of Archaeological Science,* 39**,** 2003-2011.

Robson, H. K., Andersen, S. H., Clarke, L., Craig, O. E., Gron, K. J., Jones, A. K., Karsten, P., Milner, N., Price, T. D. & Ritchie, K. 2016. Carbon and nitrogen stable isotope values in freshwater, brackish and marine fish bone collagen from Mesolithic and Neolithic sites in central and northern Europe. *Environmental Archaeology,* 21**,** 105-118.

Rosberg, A. 1994. *Mesolitiska boplatser vid Järnsjön fornlämning nr 165 Järeda sn Småland. Arkeologisk undersökning 1992. Rapport 1994:12,* Kalmar: Kalmar läns museum.

Rosenlund, K. 1971. Zoological material, In Særdborg II, A Maglemose hut from Sværdborg bog, Zealand, Denmark. *Acta Archaeologica,* 42**,** 59-62.

Rowley-Conwy, P. 1983. Sedentary hunters: the Ertebølle example. *In:* Bailey, G. N. (ed.) *Hunter-gatherer economy in prehistory.* 1-26. Cambridge: Cambridge University Press.

Rowley-Conwy, P. 1993. Season and reason: The case for a regional interpretation of Mesolithic settlement patterns. *Archeological Papers of the American Anthropological Association,* 4**,** 179-188.

Rowley-Conwy, P. 1999. Economic prehistory in southern Scandinavia. *In:* J. Coles, R. M. B., and P. Mellars (ed.) *World prehistory: Studies in memory of Grahame Clark.* 125-159. Proceedings of the British Academy 99, Oxford: Oxford University Press.

Rowley-Conwy, P. 2001. Time, change and the archaeology of hunter-gatherers: how original is the 'Original Affluent Society'. *In:* Panter-Brick, C., Layton, R. H. & Rowley-Conwy, P. (eds.) *Hunter-gatherers: an interdisciplinary perspective.* 39-72. Cambridge: Cambridge University Press.

Rowley-Conwy, P. 2014. Foragers and farmers in Mesolithic/Neolithic Europe, 5500–3900 cal BC: beyond the anthropological comfort zone. *In:* Foulds, F., Drinkall, H., Perri, A., Clinnick, D. & Walker, J. (eds.) *Wild Things: Recent Advances in Palaeolithic and Mesolithic Research.* 185-201. Oxford: Oxbow Books.

Rowley-Conwy, P. & Piper, S. 2016. Hunter-gatherer variability: developing the models for the northern coasts. *Arctic,* 69**,** 1-14.

Rowley-Conwy, P. & Zvelebil, M. 1989. Saving it for later: storage by prehistoric hunter-gatherers in Europe. *In:* Halstead, P. & O'Shea, J. (eds.) *Bad year economics: cultural responses to risk and uncertainty.* 40-56. Cambridge: Cambridge University Press.

Rozanov, Y. A. 1982. *Markov random fields,* New York: Springer.

Rule, S., Brook, B. W., Haberle, S. G., Turney, C. S., Kershaw, A. P. & Johnson, C. N. 2012. The aftermath of megafaunal extinction: ecosystem transformation in Pleistocene Australia. *Science,* 335**,** 1483-1486.

Russ, H. & Jones, A. K. 2009. Late Upper Palaeolithic fishing in the Fucino Basin, central Italy, a detailed analysis of the remains from Grotta di Pozzo. *Environmental Archaeology,* 14**,** 155-162.

Russell, N. 2011. *Social zooarchaeology: Humans and animals in prehistory,* Cambridge: Cambridge University Press.

Ryan, M. 1980. An Early Mesolithic site in the Irish midlands. *Antiquity,* 54**,** 46-47.

Rydbeck, O. 1930. The earliest settling of man in Scandinavia. *Acta Archaeologica,* 1**,** 55-87.

Säisä, M., Koljonen, M.-L., Gross, R., Nilsson, J., Tähtinen, J., Koskiniemi, J. & Vasemägi, A. 2005. Population genetic structure and postglacial colonization of Atlantic salmon (Salmo salar) in the Baltic Sea area based on microsatellite DNA variation. *Canadian Journal of Fisheries and Aquatic Sciences,* 62**,** 1887-1904.

Salomonsson, B. 1960. Vorläufiger Bericht über einen spätglazialen Wohnplatz in Schonen. *Meddelanden från Lunds universitets historiska museum,* 1960**,** 197-203.

Salomonsson, B. 1962. Sveriges äldsta kontakt med Västeuropa. En boplats vid Segebro i Skåne. *Proxima Thule,* 1962**,** 1-25.

Sanger, M. C. 2017. Evidence for Significant Subterranean Storage at Two Hunter-gatherer Sites: The Presence of a Mast-based Economy in the Late Archaic Coastal American Southeast. *American Antiquity,* 82**,** 50-70.

Sarauw, G. 1903. En stenalders boplats i Maglemose ved Mullerup, sammenholt med beslægtede fund. *Aarbøger for Nordisk oldkyndighed og historie,* 1903**,** 148-315.

Schalk, R. F. 1981. Land use and organizational complexity among foragers of northwestern North America. *In:* Koyama, S. & Thomas, D. (eds.) *Affluent Foragers, Pacific Coasts East and West.* 53-76. Osaka: National Museum of Ethnology.

Schmitt, L., Larsson, S., Schrum, C., Alekseeva, I., Tomczak, M. & Svedhage, K. 2006. 'Why They Came'; The colonization of the coast of western Sweden and its environmental context at the end of the last glaciation. *Oxford Journal of Archaeology,* 25**,** 1-28.

Schmölcke, U., Meadows, J., Ritchie, K., Bērziņš, V., Lübke, H. & Zagorska, I. 2016. Neolithic fish remains from the freshwater shell midden Riņņukalns in northern Latvia. *Environmental Archaeology,* 21**,** 325-333.

Schnittger, B. & Rydh, H. 1940. *Grottan Stora Förvar på Stora Karlsö,* Stockholm: Wahlström & Widmark.

Schoeninger, M. J. & DeNiro, M. J. 1984. Nitrogen and carbon isotopic composition of bone collagen from marine and terrestrial animals. *Geochimica et Cosmochimica Acta,* 48**,** 625-639.

Schulting, R. J. 2015. Mesolithic skull cults? *In:* Hackwitz, K. v. & Peyroteo-Stjerna, R. (eds.) *Ancient death ways Proceedings of the workshop on archaeology and mortuary practices.* 19-46. Uppsala: Uppsala University.

Segerberg, A. 1999. *Bälinge mossar. Kustbor i Uppland under yngre stenåldern,* Aun 26*,* Uppsala: Department of Archaeology and Ancient History, Uppsala University.

Seifert, T., Tauber, F. & Kayser, B. 2001. A high resolution spherical grid topography of the Baltic Sea–2nd edition, Baltic Sea Science Congress, Stockholm 25-29. November 2001. *Poster# 147.*

Selva, N., Hobson, K. A., Cortés-Avizanda, A., Zalewski, A. & Donázar, J. A. 2012. Mast pulses shape trophic interactions between fluctuating rodent populations in a primeval forest. *PloS one,* 7**,** e51267.

Seving, B. 1986. *Tre mesolitiska boplatser på Gotland. Ett försök till tolkning av relation och lokaliseringsmönster,* Bachelor Thesis*,* Stockholm: Stockholm University.

Sheehan, G. W. 1985. Whaling as an organizing focus in northwestern Alaskan Eskimo Society. *In:* Price, D. T. & Brown, J. A. (eds.) *Prehistoric hunter-gatherers: The emergence of cultural complexity.* 123-154. New York: Academic Press.

Simpson, T. 1943. *Narrative of the Discoveries on the North Coast of America: Effected by the Officers of the Hudson's Bay Company During the Years 1836-1839,* London: Richard Bentley.

Sims, N. A. & Martin, T. J. 2014. Coupling the activities of bone formation and resorption: a multitude of signals within the basic multicellular unit. *BoneKEy reports,* 3**,** 481.

Sjögren, K.-G. & Ahlström, T. 2016. Early Mesolithic Burials from Bohuslän, western Sweden. *In:* Grünberg, J. M., Gramsch, B., Larsson, L., Orschiedt, J. & Meller, H. (eds.) *Mesolithic burials – Rites, symbols and social organisation of early postglacial communities. International Conference Halle (Saale), Germany, 18th–21st September 2013.* 125-143. Halle: Landesmuseum Halle.

Sjöström, A. 1995. *Grävningsrapport. Rönneholm 4, 5, 7 och 8. Arkeologisk förundersökning av fyra mesolitiska boplatser å Hassle 32: 18, Stehag socken, Eslövs kommun, Skåne,* Lund: Department of Archaeology and Ancient History, Lund University.

Sjöström, A. 1997. Ringsjöholm. A Boreal-Early Atlantic Settlement in Central Scania, Sweden. *Lund Archaeological Review,* 3**,** 5-20.

Sjöström, A. 2004. *Rönneholm 6-10, 12, 14 och 15: arkeologisk undersökning av ett mesolitiskt boplatskomplex i Rönneholms mosse. Hassle 32: 18, Stehag socken, Eslövs kommun, Skåne,* Lund: Department of Archaeology and Ancient History, Lund University.

Sjöström, A. 2013. *Mesolitiska lämningar i Rönneholms mosse. Arkeologisk förundersökning 2012. Hassle 32: 18, Stehag socken, Eslövs kommun, Skåne,* Lund: Department of Archaeology and Ancient History, Lund University.

Skaarup, J. & Gron, O. 2004. *Møllegabet II. A submerged Mesolithic settlement in southern Denmark,* BAR International Series 1328*,* Oxford: Archaeopress.

Slack, C. R. & Hatch, M. D. 1967. Comparative studies on the activity of carboxylases and other enzymes in relation to the new pathway of photosynthetic carbon dioxide fixation in tropical grasses. *Biochemical Journal,* 103**,** 660.

Soffer, O. 1985. Patterns of Intensification as Seen from the Upper Paleolithic of the Central Russian Plain. *In:* Price, T. D. & Brown, J. A. (eds.) *Prehistoric Hunter-Gatherers: The Emergence of Cultural Complexity.* Orlando: Academic Press.

Soffer, O. 1989. Storage, sedentism and the Eurasian Palaeolithic record. *Antiquity,* 63**,** 719.

Sørensen, M. 2012. The arrival and development of pressure blade technology in southern Scandinavia. *In:* Desrosiers, P. M. (ed.) *The Emergence of Pressure Blade Making. From Origin to Modern Experimentation.* 237-259. New York: Springer.

Sørensen, M., Rankama, T., Kankaanpää, J., Knutsson, K., Knutsson, H., Melvold, S., Eriksen, B. V. & Glørstad, H. 2013. The first eastern migrations of people and knowledge into Scandinavia: evidence from studies of Mesolithic technology, 9th-8th millennium BC. *Norwegian Archaeological Review,* 46**,** 19-56.

Sørensen, S. A. 2016a. Loose human bones from Danish Mesolithic. *In:* Grünberg, J. M., Gramsch, B., Larsson, L., Orschiedt, J. & Meller, H. (eds.) *Mesolithic Burials–Rites, Symbols and Social Organisation of Early Postglacial Communities. International Conference Halle (Saale), Germany, 18th-21st September 2013.***,** 63-72. Halle: Landesmuseum Halle.

Sørensen, S. A. 2016b. Syltholm: Denmark's largest Stone Age excavation. *Mesolithic Miscellany,* 24**,** 3-10.

Sørensen, S. A. 2017. *The Kongemose Culture,* Copenhagen: The Royal Society of Northern Antiquaries.

Sponheimer, M., Robinson, T., Ayliffe, L., Roeder, B., Hammer, J., Passey, B., West, A., Cerling, T., Dearing, D. & Ehleringer, J. 2003. Nitrogen isotopes in mammalian herbivores: hair δ15N values from a controlled feeding study. *International Journal of Osteoarchaeology,* 13**,** 80-87.

Steenstrup, J. J. S. 1862. *Et blik paa natur-og oldforskningens forstudier til besvarelsen af spørgsmaalet om menneskeslaegtens tidligste optraeden i Europa,* Indbydelseskrift til Kjøbenhavns universitets Aarsfest til erindring om Kirkens Reformation*,* Copenhagen: JH Schultz.

Sten, S., Ahlström, T., Alexandersen, V., Borrman, H., Christensen, E., Ekenman, I., Kloboucek, J., Königsson, L.-K., Possnert, G. & Ragnesten, U. 2000. Barumkvinnan: nya forskningsrön. *Fornvännen,* 95**,** 73-87.

Stenberger, M. 1939. *Rapport rörande eftersökning av skelettdelar av två individer från Kanalen, Lummelunda socken, Gotland,* Unpublished report.

Stiner, M. C. & Munro, N. D. 2011. On the evolution of diet and landscape during the Upper Paleolithic through Mesolithic at Franchthi Cave (Peloponnese, Greece). *Journal of Human Evolution,* 60**,** 618-636.

Stjernquist, B. 1997. *The Röekillorna Spring: spring-cults in Scandinavian prehistory,* Acta Regiae Societatis humaniorum litterarum Lundensis 82*,* Stockholm: Almqvist & Wiksell International.

Stopp, M. P. 2002. Ethnohistoric analogues for storage as an adaptive strategy in northeastern subarctic prehistory. *Journal of Anthropological Archaeology,* 21**,** 301-328.

Storå, J. 2001. *Reading bones: Stone age hunters and seals in the Baltic,* Stockholm: Department of Archaeology, Stockholm University.

Sulgostowska, Z. 2006. The Mesolithic Communication Network. *In:* Kind, C.-J. (ed.) *After the Ice Age. Settlements, subsistence and social development in the Mesolithic of Central Europe.* 211-219. Stuttgart: Konrad Theiss Verlag.

Suttles, W. 1968. Coping with abundance: subsistence on the Northwest Coast. *In:* Lee, R. & DeVore, I. (eds.) *Man the Hunter.* 56-68. Chicago: Aldine.

Svensson, R. 2006. *Gäddan & fisket i Ringsjöholm: en osteologisk metodstudie i säsong & bevarande,* Unpublished seminar paper in Historical Osteology*,* Lund: Department of Archaeology and Ancient History, Lund University.

Szpak, P. 2011. Fish bone chemistry and ultrastructure: implications for taphonomy and stable isotope analysis. *Journal of Archaeological Science,* 38**,** 3358-3372.

Taffinder, J. 1982. *The stone age in southern Småland, a Presentation of the Existing Assemblages with Special Consideration of their Mesolithic Components,* Unpublished seminar paper in Archaeology*,* Uppsala: Uppsala University.

Tauber, H. 1981. 13C evidence for dietary habits of prehistoric man in Denmark. *Nature,* 292**,** 332-333.

Terberger, T., Gramsch, B. & Heinemeier, J. 2012. The underestimated fish?-Early Mesolithic human remains from Northern Germany. *In:* Niekus, M. J. L., Barton, R. N. E., Street, M. & Terberger, T. (eds.) *A Mind Set on Flint.* 343–354. Barkhuis: Groningen University Library.

Testart, A. 1982. The significance of food storage among hunter-gatherers: Residence patterns, population densities, and social inequalities. *Current anthropology,* 23**,** 523-537.

Thieren, E., Wouters, W., Van Neer, W. & Ervynck, A. 2012. Body length estimation of the European eel Anguilla anguilla on the basis of isolated skeletal elements. *Cybium,* 36**,** 551-562.

Thomas, S. E. 1954. Sjöholmen, Site 179. A Re-Examination. *In:* Althin, C.-A. (ed.) *The Chronology of the Stone Age Settlement of Scania, Sweden.* Acta Archaeologica Lundensia, Series in 4°, 1. Lund.

Thomsen, P. F. & Willerslev, E. 2015. Environmental DNA – An emerging tool in conservation for monitoring past and present biodiversity. *Biological Conservation,* 183**,** 4-18.

Tome, C. & Vinge, J.-D. 2003. Roe deer (Capreolus capreolus) age at death estimates: new methods and modern reference data for tooth eruption and wear, and for epiphyseal fusion. *Archaeofauna,* 12**,** 157-173.

Vanderklift, M. A. & Ponsard, S. 2003. Sources of variation in consumer-diet δ15N enrichment: a meta-analysis. *Oecologia,* 136**,** 169-182.

Vandkilde, H. 1996. *From stone to bronze: the metalwork of the late Neolithic and earliest Bronze Age in Denmark,* Aarhus: Aarhus University: Jutland Archaeological Society. Aarhus University Press.

Wada, E. 1980. Nitrogen isotope fractionation and its significance in biogeochemical processes occurring in marine environments. *Isotope marine chemistry,* 1**,** 375-398.

Wallebom, B. 2015. *Kvinnan från Barum–från äldre stenåldern: En forskningshistorik samt därtill några ställningstaganden och tillrättalägganden, kritiska anmärkningar och slutsatser,* Stockholm: Statens historiska museum.

Waxell, S. 1953. *Den stora expeditionen. Utdrag ur såväl mina egna som andra officerares journaler från den Kamtjakta-expedition, som utgick från S: t Petersburg år 1733,* Published, with a commentary, by Juri Semjonow. Stockholm: Rabén & Sjögren.

Webb, E. C., Honch, N. V., Dunn, P. J., Eriksson, G., Lidén, K. & Evershed, R. P. 2015. Compound-specific amino acid isotopic proxies for detecting freshwater resource consumption. *Journal of Archaeological Science,* 63**,** 104-114.

Weir, C. R., Stockin, K. A. & Pierce, G. J. 2007. Spatial and temporal trends in the distribution of harbour porpoises, white-beaked dolphins and minke whales off Aberdeenshire (UK), north-western North Sea. *Journal of the Marine Biological Association of the United Kingdom,* 87**,** 327-338.

Welinder, S. 1978. The concept of 'ecology' in Mesolithic research. *In:* Mellars, P. (ed.) *The Early Postglacial Settlement of Northern Europe: An ecological perspective.* 11-26. London: Duckworth.

Wesson, C. B. 1999. Chiefly power and food storage in southeastern North America. *World Archaeology,* 31**,** 145-164.

Westaway, M. C., Olley, J. & Grün, R. 2017. At least 17,000 years of coexistence: Modern humans and megafauna at the Willandra Lakes, South-Eastern Australia. *Quaternary Science Reviews,* 157**,** 206-211.

Westergren, E. 1979. *Södra Småland under yngre stenåldern och bronsåldern. En studie av bebyggelseutvecklingen i Göteryds sn,* Strömsnäsbruk: Göteryds Hembygdsförening.

Wheeler, A. 1978. Problems of identification and interpretation of archaeological fish remains. *In:* Brothwell, D. R., Thomas, K. D. & Clutton-Brock, J. (eds.) *Research problems in zooarchaeology.* 69-75. Londom: Occasional papers of the Institute of Archaeology

Wheeler, A. & Jones, A. K. 1989. *Fishes,* Cambridge: Cambridge University Press.

Widmark, G. 2015. *Huseby klev en jämförelse mellan kust och inland, en studie om jaktstrategier och resursutnyttjande under mesolitikum,* Unpublished seminar paper in Historical Osteology, Lund: Department of Archaeology and Ancient History, Lund University.

Wigforss, J. 1983. *Bua Västergård, en 8000 år gammal kustboplats,* Göteborg: Göteborgs arkeologiska museum.

Willis, D. W. 1989. Proposed standard length–weight equation for northern pike. *North American Journal of Fisheries Management,* 9**,** 203-208.

Woodburn, J. 1980. Hunters and gatherers today and reconstruction of the past. *In:* Gellner, E. (ed.) *Soviet and Western anthropology.* 95-117. London: Duckworth.

Woodburn, J. 1982. Egalitarian societies. *Man,* 17**,** 431-451.

Woodman, P. C. 1985a. *Excavations at Mount Sandel, 1973-77, County Londonderry,* Belfast: Her Majesty's Stationery Office.

Woodman, P. C. 1985b. Mobility in the Mesolithic of northwestern Europe: an alternative explanation. *In:* Price, D. & Brown, J. A. (eds.) *Prehistoric Hunter-Gatherers: The Emergence of Cultural Complexity.* 325-339. Orlando: Academic Press.

Yesner, D. R. 1980. Maritime hunter-gatherers: ecology and prehistory. *Current Anthropology,* 21**,** 727-750.

Zeder, M. A., Lemoine, X. & Payne, S. 2015. A new system for computing long-bone fusion age profiles in Sus scrofa. *Journal of Archaeological Science,* 55**,** 135-150.

13. Appendices

13.1. Clarifications

13.1.1. Personal communications

Larsson, L. 2017-17-05. Mail correspondence.

Jonsson, L. 2017-20-05. Conference discussion.

13.1.2. Online data

SGU, Swedish Geological Survey shoreline displacement map. Accessed 2014–2017. http://maps2.sgu.se/kartgenerator/maporder_sv.html

FMIS, (Sweden's National Heritage Board's database for archaeological sites and monuments). Accessed 2014–2018.
http://www.fmis.raa.se/cocoon/fornsok/search.html

13.1.3. Data accessibility

- Norje Sunnansund: The bone material from Norje Sunnansund was borrowed from the Archaeologist in Lund, National Historical Museums in Sweden. When all analyses are finished, the material will be relocated to Blekinge Museum in Karlskrona, where it will be deposited.
- Huseby Klev: The bone material from Huseby Klev was borrowed from the Archaeologist in Mölndal, National Historical Museums in Sweden.
- Gisslause: The fish bones from Gisslause were borrowed from the osteoarchaeological research laboratory in Stockholm, where they are currently located. The bones are later destined to be deposited at the Museum of Gotland.
- Radiocarbon ^{14}C data used in paper V are appended to the paper and available at: http://www.sciencedirect.com/science/article/pii/S2352409X16308392?via%3Dihub#ec0005

- Stable isotope data: the database covering all the data used in the analyses included in paper VI are appended to the paper.

13.1.4. Author contributions to the joint papers

Paper V: AB analysed the fish bone material. JS and CHV analysed the mammal bones. The radiocarbon dates were gathered by JA, JS and AB. AB, JS and JA analysed the data and wrote the paper together.

Paper VI: AB designed the study, collected the material and sampled the bones. AB created figures 1, 3, 4, table 1, table 2 and the supplementary files. TA created figure 2 and table 3. AB and TA analysed the data and wrote the paper together.

13.2. Fish bone measurements from Norje Sunnansund

Table A 1 Largest width of the posterior articulation of the first vertebra on cyprinids from Norje Sunnansund (mm).

1.5	3.44	3.7	4	4.2	4.4	4.6	5	5.6
2.16	3.48	3.7	4	4.2	4.4	4.6	5	5.63
2.62	3.5	3.74	4	4.2	4.4	4.6	5	5.7
2.64	3.5	3.77	4	4.2	4.4	4.62	5	5.7
2.7	3.51	3.8	4	4.2	4.4	4.63	5.04	5.7
2.8	3.52	3.8	4	4.2	4.4	4.66	5.1	5.78
2.8	3.55	3.8	4	4.2	4.4	4.66	5.1	5.8
2.8	3.56	3.8	4.05	4.2	4.4	4.67	5.1	5.8
2.9	3.6	3.8	4.05	4.2	4.41	4.7	5.1	5.9
2.97	3.6	3.8	4.06	4.21	4.47	4.7	5.1	5.9
3	3.6	3.8	4.1	4.25	4.5	4.7	5.1	5.9
3	3.6	3.8	4.1	4.25	4.5	4.7	5.1	6
3	3.6	3.8	4.1	4.3	4.5	4.7	5.12	6
3	3.6	3.8	4.1	4.3	4.5	4.7	5.2	6
3.03	3.6	3.85	4.1	4.3	4.5	4.7	5.2	6.2
3.06	3.6	3.9	4.1	4.3	4.5	4.77	5.2	6.3
3.1	3.66	3.9	4.1	4.3	4.5	4.8	5.2	6.4
3.1	3.7	3.9	4.1	4.3	4.5	4.8	5.31	6.4
3.1	3.7	3.9	4.1	4.3	4.5	4.8	5.4	6.5
3.1	3.7	3.9	4.1	4.3	4.5	4.8	5.4	6.7
3.1	3.7	3.9	4.1	4.3	4.5	4.8	5.4	7.2
3.11	3.7	3.93	4.1	4.3	4.52	4.8	5.4	7.5
3.21	3.7	3.94	4.1	4.31	4.55	4.84	5.4	7.7
3.25	3.7	3.94	4.13	4.35	4.6	4.87	5.4	8.2
3.3	3.7	3.94	4.16	4.36	4.6	4.9	5.4	9.4
3.3	3.7	3.97	4.17	4.37	4.6	4.9	5.5	
3.3	3.7	3.97	4.2	4.38	4.6	4.9	5.5	
3.4	3.7	3.98	4.2	4.4	4.6	4.9	5.5	
3.41	3.7	4	4.2	4.4	4.6	5	5.6	

Table A 2 Anterior height of dentale on pike from Norje Sunnansund (mm).

2.6	4.1	4.3	4.4	5.09	5.2	5.6	5.8	6.5
3.5	4.3	4.3	4.8	5.1	5.3	5.8	6.2	6.6
3.7	4.3	4.3						

Table A 3 Smallest medio-lateral middle breadth of parasphenoidale on pike from Norje Sunnansund (mm).

3.2	7.9	3.5	2.8	2.4	2.9

Table A 4 Anterior height of dentale on perch from Norje Sunnansund (mm).

2.86	3.1	3.1	3.14	3.5	3.7	3.82	5.8

Table A 5 Length of corpus on precaudal vertebrae types 3, 4, 5, 6 and the anterior-posterior height of midshaft cleitrum (mm).

PC Vert 3	PC Vert 4	PC Vert 5	PC Vert 6	Cleitrum
3.94	2.75	3.26	3.54	2.3
	3.41	3.5	4	3.71
	3.68	3.6	4.37	3.78
		4.06	6.5	3.88
		4.2		
		4.5		
		5.5		

13.3. Bone element frequencies from Norje Sunnansund, Huseby Klev and Gisslause

(following pages)

Table A 6 Mammal bone element frequencies from Norje Sunnansund.

	Calvarium	Cornu	Dentes	Mandibula	Vertebrae	Costae	Clavicula	Scapula	Humerus	Radius	Ulna	Carpalia	Metacarpalia	Coxae	Femur	Tibia	Fibula	Tarsalia	Metatarsalia	Phalannges	Sesamoide	Metapodia	Other	Sum
Red deer (*Cervus elaphus*)	11	122	55	10	11	3		2	5	7	5	15	17	7	9	10		12	11	43	9	9		373
Roe deer (*Capreolus capreolus*)	4	11	31	15	19	15		9	9	18	5	11	16	8	12	15		12	17	31	6	7		271
Elk (*Alces alces*)		5	2	1	1								2		1			2	1	4				19
Cervidae indet.		23	1		2			1								3			1					31
Aurochs (*Bos primigenius*)			1		21	3		1	1									1	1	3				32
Wild boar (*Sus scrofa*)	17		100	9	21	18		9	9	16	2	13	4	8	10	12	2	16	8	41	8	8		331
Grey seal (*Halichoerus grypus*)	20		26	2	3					2	1	4	1	3	2	4	1	4		2	2			77
Ringed seal (*Pusa hispida*)	4		11		1	2		2	6	1	2		1	5	2	2	2			1				42
Phocidae indet.	53		14		2	16		2	1	2		2	6	6	3		3	3	3	49	5	2		172
Brown bear (*Ursus arctos*)	1		8		1	5						1								2		1		19
Wolf (*Canis lupus*)				1		1			1				2	1		2				5		1		14
Red fox (*Vulpes vulpes*)	1		5	2		2				2	2							1	1	4		2		22
Dog (*Canis familiaris*)	1		3		1	10								1	2	3		1	3	5		2		32
Canidae indet.	3		3		1				1							1				2				11
Badger (*Meles meles*)	1		2			8			1	1	1						3	5	3	4				29
Otter (*Lutra lutra*)	4		3	2	4	6			2		4	1		3				3		4				36
Pine marten (*Martes martes*)	3		10	7	4					1			1		1	1	1	1		9		3		42
European polecat (*Mustela putorius*)				1																				1
Wild cat (*Felis silvestris*)	1		2	1					1		1									2		1		9
Carnivora indet.			3		1	2																		6
European hedgehog (*Erinaceus europaeus*)			1	3									1		1	1								7
Mountain hare (*Lepus timidus*)																			1					1
Beaver (*Castor fiber*)			11	3	1											1				1				17
Red squirrel (*Sciurus vulgaris*)	1		21	4	1		1		4	4	4		1		4	6		3	2	1				57
Water vole (*Arvicola amphibius*)	10		22	25	4				3		2			1	3			2						72
Field vole (*Microtus agrestis*)	1		1	12																				14
Yellow-necked mouse (*Apodemus flavicollis*)	1			8																				9
Rodent indet. (Rodentia)	1		66	1	29				16	3	2	1		5	12	6		3				1	12	158
Human (*Homo sapiens*)	21		12	1																2				36

Table A 7 Bird bone element frequencies from Norje Sunnansund

	Calvarium	Mandibula	Vertebrae	Sternum	Furcula	Coracoid	Scapula	Humerus	Radius	Ulna	Carpalia	Carpometacarpus	Coxae	Femur	Tibiotarsus	Fibula	Tarsometatarsus	Phalannges	Sum
Northern shoveler (*Anas clypeata*)								1	2				1						4
Eurasian wigeon (*Anas penelope*)												1			1				2
Mallard (*Anas platyrhynchos*)	1			1		3	1	1				1		1	3		1		13
Garganey (*Anas querquedula*)										1									1
Northern pintail (*Anas acuta*)										1									1
Common pochard (*Aythya ferina*)						1													1
Tufted duck (*Aythya fuligula*)					1	1				2									4
Greater scaup (*Aythya marila*)							1			1									2
Common goldeneye (*Bucephala clangula*)				1			1			1				1					4
Long tailed duck (*Clangula hyemalis*)										1									1
Common eider (*Somateria mollissima*)										1									1
Velvet scoter (*Melanitta fusca*)					1			1		2				1	2				7
Common scoter (*Melanitta nigra*)										1									1
Common merganser (*Mergus merganser*)				1	1	2			1			1			1				7
Red-breasted merganser (*Mergus serrator*)				1			1												2
Greylag goose (*Anser anser*)		1					2	1	2	1							1		8
Bean goose (*Anser fabalis*)								2											2
Anserini indet.								1		1									2
Anatidae indet.			1			1		2		2		1			1				8
Great crested grebe (*Podiceps cristatus*)								1						1	1				3
Red-necked grebe (*Podiceps grisegena*)						1													1
Black-throated loon (*Gavia arctica*)								1				2							3
Red-throated loon (*Gavia stellata*)	1									1				1					3
Great cormorant (*Phalacrocorax carbo*)	1		2					1	1	1			1			1	1	1	10
Grey heron (*Ardea cinerea*)								2											2
Carrion crow (*Corvus corone*)						2	1										2		5
Spotted nutcracker (*Nucifraga caryocatactes*)										1									1
Corvidae indet.						3											1		4
Western capercaillie (*Tetrao urogallus*)											1								1
Red kite (*Milvus milvus*)						1													1
White-tailed eagle (*Haliaeetus albicilla*)								1											1

Table A 8 Fish bone element frequencies from Norje Sunnansund. *=basalia, radialia, pterygiophore, interspinalia, spina/pinna dorsalis, interhaemal

	Parasphenoidale	Vomer	Frontale	Interparietale	Neurocrania unspec.	Basioccipitale	Premaxillare	Maxillare	Dentale	Articulare	Quadratum	Palatinum	Lacrimale	Ectopterygium	Metapterygoideum	Preoperculare	Interoperculare	Suboperculare	Operculare	Hyomandibulare	Keratohyale	Epihyale	Hypohyale	Glossohyale	Urohyale	Branchiale	Dentes	Pharyngea	Posttemporale	Supracleitrale	Cleitrum	Basipterygium	Coracoid	Scapula	Weberian bones	Costae	Pinnae*	Squama	Vertebrae 1-5	Precaudal vertebrae	Caudal vertebrae	Vertebrae unspec.	Sum
Cyprinids indet. (Cyprinidae)	16	1			14	117		5	23	41	24					2			13	9	91	7	28		10	5		735	1		7	95	7	21	12	73	61		690	2959	4278	1363	10708
Cyprinids (*Rutilus*/*Leuciscus*)																																							161				161
Roach (*Rutilus rutilus*)						52																						964															1016
Silver bream (*Blica bjoerkna*)																												3															3
Bream (*Abramis brama*)						3			1																			15											1				20
European chub (*Squalius cephalus*)																												6															6
Crucian carp (*Carassius carassius*)						2																						6															8
Rudd (*Scardinius erythrophthalmus*)																												13															13
Dace (*Leuciscus leuciscus*)																												11															11
Tench (*Tinca tinca*)						1																						18															19
Bleak (*Alburnus alburnus*)																												6															6
Ide (*Leuciscus idus*)																												7															7
Perch (*Perca fluviatilis*)	5	5	2			17	12	8	12	1	6	1	1	4		7	3	2	10	6	9	2							6	11	3	6				2	44	4	137	978	900	524	2728
Pike perch (*Sander lucioperca*)	1																																						5	6	20	21	53
Ruffe (*Gymnocephalus cernua*)																1				1																			1	20	12		35
Percidae indet.					1																																4			7	1		13
Pike (*Esox lucius*)	19	8		10	1	13	1	7	53	26	33	55		33	1					2	7			3	7	1	67	2			13					7			28	239	279	183	1098
Burbot (*Lota lota*)							1				1																												8	29	30	14	83
Arctic char (*Salvelinus alpinus*)																																										3	3
Whitefish (*Coregonus*)																																							1	9	9	13	32
Trout (*Salmo trutta*)																																									1		1
Salmonids indet. (Salmonidae)																													1											2	4		7
Salmon (*Salmo salar*)																																										1	1
Eel (*Anguilla anguilla*)						1			1	1																					3									7	102	23	138
Smelt (*Osmerus eperlanus*)						2																																		5	3		10

Table A 9 Mammal bone element frequencies from Huseby Klev PBO-EBO phase.

	Calvarium	Cornu	Dentes	Mandibula	Vertebrae	Costae	Scapula	Humerus	Radius	Ulna	Carpalia	Metacarpalia	Coxae	Femur	Tibia	Fibula	Tarsalia	Metatarsalia	Phalannges	Sesamoide	Metapodia	Sum
Red deer (*Cervus elaphus*)	1	7	1		2	2	1		1		3		2		2		3	2	2		2	31
Roe deer (*Capreolus capreolus*)	2	1		1	1	1			2						1		1				1	11
Elk (*Alces alces*)	1		1				1			1												4
Reindeer (*Rangifer tarandus*)		2											1									3
Wild boar (*Sus scrofa*)	9		11	2	17	7	4	4	1	1	3		1	4	1		4	2	10			81
White-beaked dolphin (*Lagenorhynchus albirostris*)	8				101	28				1									2			140
Harbour porpoise (*Phocoena phocoena*)	2				25																	27
Dolphins (Dolphinidae)					4																	4
Grey seal (*Halichoerus grypus*)	12		3	1	2	1	2	1	1	2		1		1				1				28
Harbour seal (*Phoca vitulina*)			2		1		1															4
Phocidae indet.															2				1			3
Brown bear (*Ursus arctos*)			1																2			3
Red fox (*Vulpes vulpes*)					3			3	1								1					8
Dog (*Canis familiaris*)					2				1													3
Badger (*Meles meles*)												1										1
Otter (*Lutra lutra*)				1				1		3												5
Pine marten (*Martes martes*)																			1			1
European hedgehog (*Erinaceus europaeus*)			1																			1
Beaver (*Castor fiber*)			1	1																		2
Water vole (*Arvicola amphibius*)			2	2																		4
Human (*Homo sapiens*)	2																					2

Table A 10 Mammal bone element frequencies from Huseby Klev MBO phase.

	Calvarium	Cornu	Dentes	Mandibula	Vertebrae	Costae	Scapula	Humerus	Radius	Ulna	Carpalia	Metacarpalia	Coxae	Femur	Tibia	Fibula	Tarsalia	Metatarsalia	Phalannges	Sesamoide	Metapodia	Sum
Red deer (*Cervus elaphus*)	2	1	2		1		1	3			2			1	3							16
Roe deer (*Capreolus capreolus*)	1		3			3	2	5			3	2	2		7		8		7	1		44
Wild boar (*Sus scrofa*)	5		14	1	2				1		3			2			3	1	7	1		40
White-beaked dolphin (*Lagenorhynchus albirostris*)					2		1															3
Harbour porpoise (*Phocoena phocoena*)					1																	1
Grey seal (*Halichoerus grypus*)								1														1
Brown bear (*Ursus arctos*)	1																					1
Wolf (*Canis lupus*)	2		4																			6
Red fox (*Vulpes vulpes*)	2		2		4			3									1					12
Otter (*Lutra lutra*)														1								1
Wild cat (*Felis silvestris*)			4	3	1								1						1			10
Red squirrel (*Sciurus vulgaris*)															1		1					2
Water vole (*Arvicola amphibius*)	1		9	2																		12
Rodent other (Rodentia)			2																			2

Table A 11 Mammal bone element frequencies from Huseby Klev MAT phase.

	Calvarium	Cornu	Dentes	Mandibula	Vertebrae	Costae	Scapula	Humerus	Radius	Ulna	Carpalia	Metacarpalia	Coxae	Femur	Tibia	Fibula	Tarsalia	Metatarsalia	Phalannges	Sesamoide	Metapodia	Sum
Red deer (*Cervus elaphus*)		20	4			3	2	1						1				1	1			33
Roe deer (*Capreolus capreolus*)		2	38	3	1							1			2		2	4	1			54
Elk (*Alces alces*)				2															1			3
Wild boar (*Sus scrofa*)			21	1											1				1			24
Grey seal (*Halichoerus grypus*)			8																1			9
Ringed seal (*Pusa hispida*)	2		3																			5
Red fox (*Vulpes vulpes*)			3		1														5			9
Dog (*Canis familiaris*)			11	1			1												1			14
Otter (*Lutra lutra*)																	1		2			3
Wild cat (*Felis silvestris*)																	1					1
European hedgehog (*Erinaceus europaeus*)				1																		1
Beaver (*Castor fiber*)			1																			1
Red squirrel (*Sciurus vulgaris*)			5																			5
Water vole (*Arvicola amphibius*)			6					1														7
Rodent other (Rodentia)			6	1									1									8

Table A 12 Bird bone element frequencies from Huseby Klev PBO–EBO phase.

	Calvarium	Vertebrae	Sternum	Coracoid	Scapula	Humerus	Radius	Coxae	Femur	Tibiotarsus	Fibula	Tarsometatarsus	Sum
Razorbill (*Alca torda*)				1									1
Black guillemot (*Cepphus grylle*)						1							1
Great auk (*Pinguinus impennis*)	1	1		3		5		2	2	2		2	18
Common murre (*Uria aalge*)		1	1	8		4							14
Thick-billed murre (*Uria lomvia*)						1							1
Anatidae						3							3
Common goldeneye (*Bucephala clangula*)									1				1
Whooper swan (*Cygnus cygnus*)						1							1
Long-tailed duck (*Clangula hyemalis*)				1									1
Velvet scoter (*Melanitta fusca*)		1	1	3		2	1						8
Common scoter (*Melanitta nigra*)				3									2
Common eider (*Somateria mollissima*)		2	1			1				3			7
Great crested grebe (*Podiceps cristatus*)						3							3
Black-throated loon (*Gavia arctica*)			1	2									3
Red-throated loon (*Gavia stellata*)				1	1					1			3
European herring gull (*Larus argentatus*)						2						1	3
Great black-backed gull (*Larus marinus*)					1	2							3
Great cormorant (*Phalacrocorax carbo*)			2	2									4

Table A 13 Bird bone element frequencies from Huseby Klev MBO phase.

	Vertebrae	Costae	Sternum	Coracoid	Scapula	Humerus	Ulna	Carpometacarpus	Femur	Tibiotarsus	Fibula	Tarsometatarsus	Phalannges	Sum
Razorbill (*Alca torda*)				1			1							2
Great auk (*Pinguinus impennis*)	1	1		4	2	9			3			1		21
Common murre (*Uria aalge*)			4			1				1				6
Velvet scoter (*Melanitta fusca*)				1		1		1		1				4
Common eider (*Somateria mollissima*)				1		2								3
Great crested grebe (*Podiceps cristatus*)				1										1
European herring gull (*Larus argentatus*)				3							1			4
Manx shearwater (*Puffinus puffinus*)							1							1
Great cormorant (*Phalacrocorax carbo*)	1			2								1		4
White-tailed eagle (*Haliaeetus albicilla*)													3	3
Eurasian nuthatch (*Sitta europaea*)						1								1

Table A 14 Bird bone element frequencies from Huseby Klev MAT phase.

	Coracoid	Scapula	Humerus	Ulna	Carpometacarpus	Femur	Tarsometatarsus	Sum
Razorbill (*Alca torda*)			1					1
Great auk (*Pinguinus impennis*)			4			1		5
Common murre (*Uria aalge*)			1					1
Long-tailed duck (*Clangula hyemalis*)						1		1
Velvet scoter (*Melanitta fusca*)		1						1
Black-throated loon (*Gavia arctica*)							1	1
Red-throated loon (*Gavia stellata*)				1			1	2
Common gull (*Larus canus*)			1		1			2
Red-breasted merganser (*Mergus serrator*)	1							1

Table A 15 Fish bone element frequencies from Huseby Klev PBO–EBO phase. *=basalia, radialia, pterygiophore, interspinalia, spina/pinna dorsalis, interhaemal

	Parasphenoidale	Vomer	Frontale	Neurocrania unspec.	Otolith	Basioccipitale	Premaxillare	Maxillare	Dentale	Articulare	Quadratum	Palatinum	Preoperculare	Suboperculare	Operculare	Hyomandibulare	Keratohyale	Epihyale	Branchiale	Posttemporale	Cleitrum	Pinnae*	Vertebrae 1-5	Vertebrae unspec.	Sum
European hake (*Merluccius merluccius*)																								5	5
Cod (*Gadus morhua*)	3	2	4	1	2	4	4	1	3	6	4	2	4	1	1	1	2	1	1	3	1		26	133	210
Whiting (*Merlangius merlangus*)																								1	1
Pollock (*Pollachius virens*/*pollachius*)																								5	5
Atlantic mackerel (*Scomber scombrus*)																								7	7
European plaice (*Pleuronectes platessa*)																						1		10	11
Spurdog (*Squalus acanthias*)																						12		17	29

Table A 16 Fish bone element frequencies from Huseby Klev MBO phase.

	Parasphenoidale	Vomer	Premaxillare	Maxillare	Dentale	Articulare	Quadratum	Pharyngea	Posttemporale	Supracleitrale	Cleitrum	Pinnae*	Squama	Vertebrae unspec.	Sum
Herring (*Clupea harengus*)						1								156	157
Ling (*Molva molva*)			4	1	1	1			1	1				86	95
Cod (*Gadus morhua*)	2	1	5	1	4	2	1							94	110
Haddock (*Melanogrammus aeglefinus*)			1												1
Whiting (*Merlangius merlangus*)														3	3
Pollock (*Pollachius virens*/*pollachius*)			3	4						3	1			38	49
Gray gurnard (*Eutrigla gurnardus*)														2	2
Ballan wrasse (*Labrus berggylta*)								1							1
Atlantic mackerel (*Scomber scombrus*)														1	1
Flounders (Pleuronectidae)														1	1
European plaice (*Pleuronectes platessa*)														31	31
Thornback ray (*Raja clavata*)													8		8
Spurdog (*Squalus acanthias*)												15		98	113

Table A 17 Fish bone element frequencies from Huseby Klev MAT phase.

	Parasphenoidale	Neurocrania unspec.	Otolith	Dentale	Dentes	Pinnae*	Vertebrae unspec.	Unspecified	Sum
Codfish (Gadidae)				2	1				3
Ling (*Molva molva*)				2					2
Cod (*Gadus morhua*)	5	1	162	4	1		86	7	266
Haddock (*Melanogrammus aeglefinus*)			29				2		31
Whiting (*Merlangius merlangus*)			7						7
Pollock (*Pollachius virens*/*pollachius*)			20				6	137	163
Gray gurnard (*Eutrigla gurnardus*)							2		2
Flounders (Pleuronectidae)							3		3
European plaice (*Pleuronectes platessa*)							16	1	17
Spurdog (*Squalus acanthias*)						2			2

Table A 18 Mammal bone element frequencies at Gisslause. *Some fragments, from both seal and hare, not determined to element are excluded (cf. NISP in paper V).

	Cranium	Teeth	Backbone	Rib cage	Front extremity	Rear extremity	Front flipper	Rear flipper	Flipper				Sum
Grey seal (*Halichoerus grypus*)	14	26	4		4	2	5	9					64
Ringed seal (*Pusa hispida*)	37	17			5	12	2	12					85
Phocidae indet.*	81	17	65	48	31	65	40	112	7				466
	Dentes	Vertebrae	Scapula	Humerus	Radius	Metacarpalia	Coxae	Femur	Tibia	Tarsalia	Metatarsalia	Phalannges	Sum
Mountain hare (*Lepus timidus*)*	7	4	1	2	1	4	1	2	2	2	2	1	29

Table A 19 Fish bone element frequencies at Gisslause.

	Parasphenoidale	Vomer	Basioccipitale	Dentale	Articulare	Quadratum	Palatinum	Ectopterygoideum	Operculare	Hyomandibulare	Keratohyale	Urohyale	Dentes	Pharyngea	Cleitrum	Vertebrae 1-5	Precaudal vertebrae	Caudal vertebrae	Vertebrae unspec.	Sum
Perch (*Perca fluviatilis*)	1		1	2												2	19	11	9	45
Pike (*Esox lucius*)	13			15		5	8	2				1	1		4		5	10	3	67
Perchpike (*Sander lucioperca*)																2	1	1		4
Cyprinid (Cyprinidae)			1						2	1	1			40		8	25	33	21	132
Burbot (*Lota lota*)		1	3	2	1	1										6	59	43	12	128
Salmonid (Salmonidae)																		1		1
Whitefish (Coregonus)																	10	31		41
Eel (*Anguilla anguilla*)																	1	2		3
Arctic char (*Salvelinus alpinus*)																	1	1		2

Paper I

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Something rotten in Scandinavia: The world's earliest evidence of fermentation

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A B S T R A C T

Large-scale food storage has been identified at an Early Mesolithic settlement on the east coast of Sweden, implying a delayed-return subsistence strategy. The excavation and analysis of the contents of a 9200-year-old construction, combined with ethnographic analogies and modern knowledge of microbial activity, suggest that fish was fermented at the site. The identification of a foraging economy fermenting substantial amounts of fish, and conserving it for later use, thousands of years prior to farming and urbanized communities and without the use of salt, has implications for how we perceive the Early Mesolithic, suggesting semi-sedentism, technological skill and the ability to adapt rapidly to changing environmental conditions. Evidence of a delayed-return practice in Early Mesolithic foraging contexts raises questions regarding the current models used to estimate demographic parameters, such as population density and birth rate, for that time period, as well as indicating the existence of a more complex society than previously realized.

1. Introduction

Mesolithic research has focused on many aspects of society, from stone technology to mobility patterns and hunting practice. However, even though diet and subsistence strategies are common research topics, the actual food preparation and cooking processes have not been examined in the same detail (Milner, 2009). If it is assumed that only limited options were available during the Mesolithic, and any processing carried out was simply to make the food edible or taste better, this lack of research may be acceptable. However, if the aim of the food preparation was to enable long-term storage, further research is warranted: more complex planning and a delayed-return strategy are commonly used as criteria for identifying complex societies and an increasing degree of sedentism (Rowley-Conwy, 1983; Cunningham, 2011).

It is known from ethnographic studies of modern and historical foraging societies that the processes of smoking and drying food products are used to facilitate food preservation and storage (Ingold, 1983), providing analogies for the possible preservation of food products during both the Paleolithic and Mesolithic (Milner, 2009). However, these techniques are relatively simple and are often interpreted as indicating the use of small-scale, short-term storage practices by prehistoric foragers (Cunningham, 2011). Furthermore, these preservation techniques are time consuming, because the meat needs to be cut into appropriately sized pieces and hung on supports; even though large amounts of meat can be preserved in this way, it is a labor-intensive process (Stopp, 2002). Therefore, in circumpolar ethnographic societies relying heavily on fish for sustenance (e.g. the Kamchadals in Kamchatka), short fishing seasons with large catches prohibit the drying and smoking of all the fish needed for the winter, so most of the fish is instead conserved through fermentation, which is done in stone and earth-covered holes in the ground (Jochelson, Unpublished typescript of MS). The weather is also important regarding the choice of preservation technique: in some regions the climate can be too damp to dry fish and meat, hence fermentation is often practiced (Eidlitz, 1969).

Indirect evidence of large-scale storage in early foraging communities is provided with the presence of devices and traps that were used to capture large numbers of animals (Rowley-Conwy and Zvelebil, 1989). However, the lack of any direct evidence in the Mesolithic has led to delayed-return strategies being associated exclusively with Neolithic farming communities, where pottery, granaries and silos for large-scale cereal storage can easily be recognized (Cunningham, 2011). The lack of evidence of long-term and large-scale storage has been seen as evidence of mobile and less complex societies, the implication being that longer term storage equates with higher social complexity (Cunningham, 2011).

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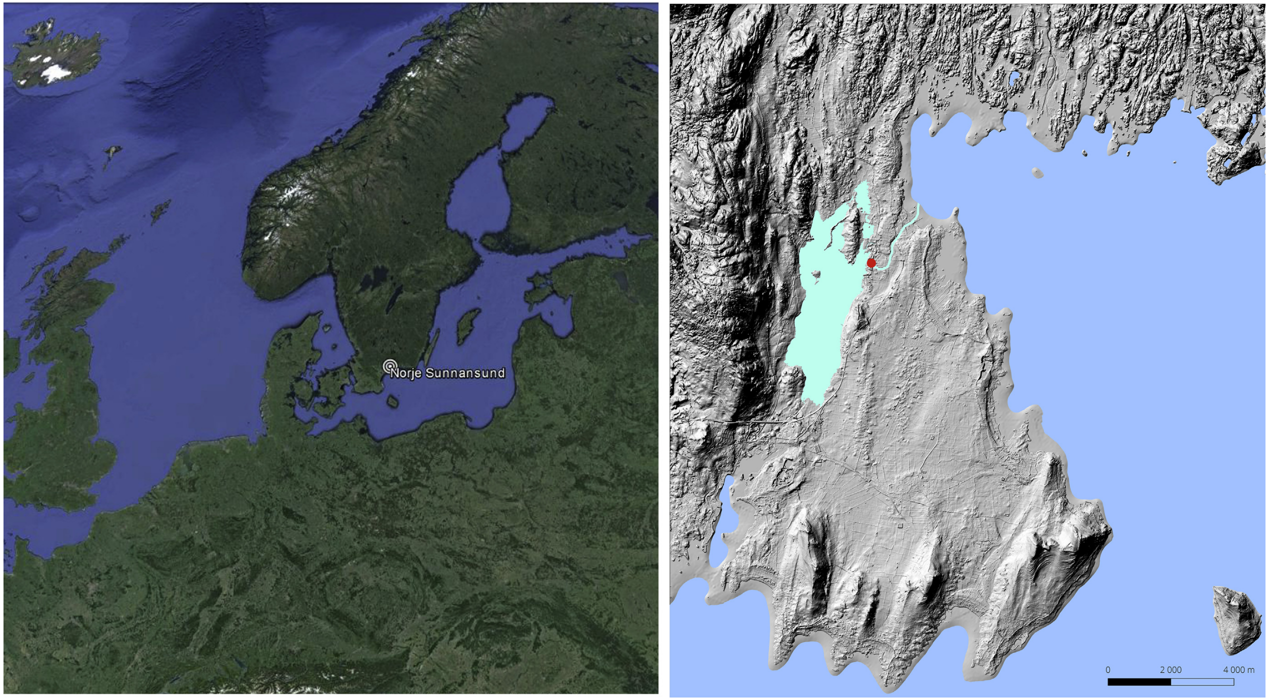

Fig. 1. The location of Norje Sunnansund (left) and the surrounding area around 9200 cal. BP (right). The map on the right is based on a terrain model at a 5-m resolution and on LIDAR data and topographic information from the Swedish Land Survey [© Lantmäteriet i2012/892], Swedish Geological Survey and Iowtopo2 (Seifert et al., 2001). Map by Nils-Olof Svensson, Kristianstad University. Picture on the left from Google Earth.

The consequences of this are that small-scale storage strategies can be considered for most types of foraging communities (Cunningham, 2011; Stopp, 2002) but large-scale storage does not easily fit within this paradigm and, accordingly, is not often considered in Mesolithic contexts.

An indication of large-scale storage and the preservation of substantial quantities of food within a foraging society have been revealed during the excavation of Norje Sunnansund, an Early Mesolithic settlement site on the coast of south-eastern Sweden. Substantial quantities of fish bone were found in and around a previously unknown type of gutter feature. Because no archaeological accounts of similar occurrences are known, these findings were interpreted with the heuristic use of ethnographic analogies and knowledge from the modern food industry. Analyzing the remains from the unique gutter feature provided a means of addressing questions such as how large-scale storage can be traced in archaeological foraging contexts, what preservation techniques were applied to larger quantities of fish and how these findings impact our understanding of early foraging societies in northern Eurasia.

2. Material

The archaeological site of Norje Sunnansund is dated to around 9600–8600 cal. BP and is located in south-eastern Sweden, on the shores of the ancient Lake Vesan, next to a 2-km long outlet leading to the Baltic basin (Fig. 1).

The site was located in an ecotone environment with access to three different types of water body and surrounded by a pine and hazel-dominated forest, with a low mountain ridge to the west adding to the environmental diversity. The site was occupied during two separate phases. The older phase has been dated to around 9600–9000 cal. BP and is recognized as a dark clayey organic layer with good preservation. The younger phase is recognized as a sandy layer covering the older layer, dated to approximately 9000–8600 cal. BP. The contents of the gutter feature were dated to between 9600 and 9000 cal. BP (Fig. 2), contemporaneous with the oldest cultural layer at the site.

The site appeared to have been occupied during most parts of the year, from late summer to late spring, with the majority of seasonality indicators being from the coldest part of the year. The seasonality indicators included the presence of ringed seal, grey seal and roe deer fetuses (all found in the cultural layer just outside the gutter), young seal calves, red deer antlers attached to skulls, fully grown small fur-bearing game species, a wide array of different migratory bird species. and archaeobotanical evidence of wild cherry (*Prunus avium*), bird cherry (*Prunus padus*), hawthorn (*Crataegus*), hazel catkins (*Corylus avellana*) and sloan (*Prunus spinosa*) (Kjällquist et al., 2016, Lagerås et al., forthcoming). The site is therefore the earliest identified winter season/all-year round settlement from southern Scandinavia, as well as the earliest known east coast settlement.

Osteological analysis of the overall animal bone assemblage from the site indicated a predominantly fish diet, with an estimated >60 tons of caught freshwater fish represented within the excavated area (Boethius, in press). The assemblage also included

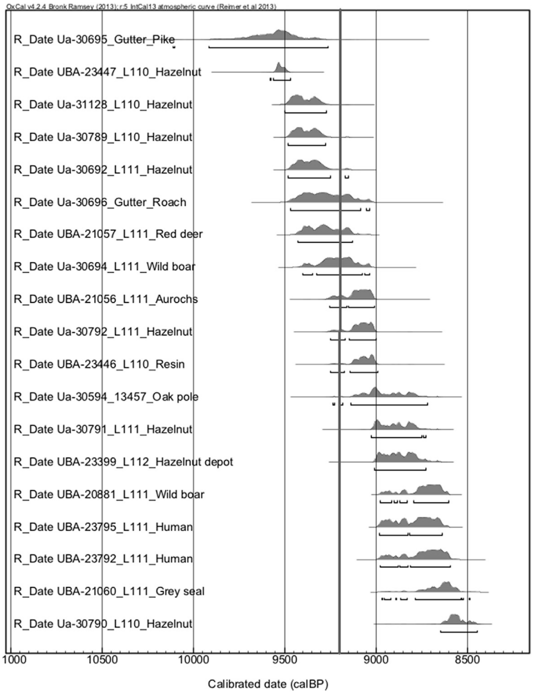

Fig. 2. The calibrated C^{14} dates from Norje Sunnansund (95.4%). Two separate phases are indicated, with large dating spans because of a calibration plateau. The 9.2 cold event, which significantly lowered the temperature of the Northern Hemisphere and affected the lives of people living here (see discussion), is indicated by a horizontal line.

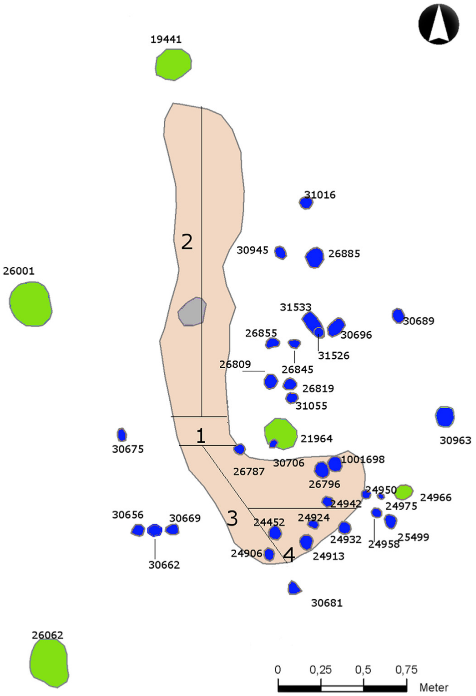

Fig. 3. Plan of the gutter with the four western sections excavated using a 2.5-mm sieve and the eastern section excavated using a 5-mm sieve. The position of the smaller stakeholes (blue) and the larger postholes (green) are marked. The grey polygon in the center of the gutter is a stone that had been placed there during the use of the gutter. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

a wide array of different mammals and birds (Boethius, forthcoming), with a larger species diversity represented than at contemporaneous Scandinavian sites; this diversity was revealed by careful excavation, fine-mesh water sieving and good preservation.

The analysis presented here is of the bone assemblage from the fill of the remains of the gutter feature and its related postholes and stakeholes, as well as the shape, location and find circumstances of the feature, together with the heuristic use of ethnographic and modern analogies. The feature appeared to be a 2.8-m long and 0.4-m wide gutter-shaped pit, which had been broadened at the southern end to a width of about 0.9 m (Figs. 3 and 4). The feature was discovered beneath the oldest cultural layer, which at this location held large quantities of fish bone and pine bark. Only the lowest part of the gutter, at a depth ranging between 0.1 and 0.2 m, could be distinguished from the contemporaneous cultural layer, which was superimposed on it. The lowest parts were distinguishable because they had been dug into the underlying clay and therefore the fill in the lower parts of the feature had not become homogenized with the contemporaneous cultural layer, which had happened to the upper part of the former construction. Hence, only the bone material from the lower part of the construction and the surrounding stakeholes and postholes (see methods) is included in this study (Table 1).

Fig. 4. A view of the gutter after 50% of it had been removed. Notice the stark contrast with the surrounding clay under the gutter as well as between the stakeholes and the surrounding clay. Photo: SHMM.

3. Methods

The gutter was hand excavated using a trowel and divided into six different sections, to obtain as much information as possible. First, the transition area between the cultural layer and the gutter was cleaned, in order to find the boundaries of the gutter, and the soil from this clean-up was collected and water-sieved using a 2.5-mm sieve. The gutter itself was then split in half and the western part was excavated in four sections, using a 2.5-mm sieve, in order to detect any possible patterns in the gutter assemblage. The eastern half of the gutter was excavated and sifted as one section, using a 5-mm sieve (Fig. 3). Different sieves were applied to save time and to estimate differences in recovery rate when using different mesh sizes. The related post- and stakeholes were all excavated with a diagonal section splitting them in half, and the soil from the excavated half was sifted using a 2.5-mm sieve.

The data was quantified using NISP (number of identified specimens) and MNI (minimum number of individuals). Correspondence analysis was carried out using the ca package in R (Nenadic and Greenacre, 2007), to distinguish and illustrate patterns and trends within the construction and across the entire excavation area.

The osteological fragments were identified, where possible, to species level, using the comparative collection at the National Historical Museums in Lund and the collection at the Zoological Museum, Copenhagen University. Cyprinid elements were only determined to family level, except for the pharyngeal and basioccipital bones, which are the most accurate for identifying cyprinids to species level.

Table 1
The bone material from the gutter and the corresponding stake- and postholes (spatial distribution shown in Fig. 3). The soil from some of the adjacent stakeholes was not sifted separately: these are shown together and indicated with a + sign; their NISP and MNI/L of sieved soil values are based on their combined volume.

	Context	Fish		Mammal		Bird		Micro- fauna	Amphibia	Fish bone frequency	
		NISP	MNI	NISP	MNI	NISP	MNI	NISP	NISP	NISP/L	MNI/L
Gutter	Western section 2.5 mm sieve	6756	205	5	3	1	1	29	0	72	2.2
	Eastern section 5 mm sieve	418	23	2	2	1	1	1	1	4	0.2
	Cleanup 2.5 mm sieve	1851	65	14	1	2	1	5	2		
Stakeholes	A24452	31	4	0	0	0	0	0	0	99	13
	A24906	31	1	0	0	0	0	0	0	53	2
	A24913	45	5	0	0	0	0	0	0	42	5
	A24924	39	3	1	1	0	0	0	0	99	8
	A24932	22	3	0	0	0	0	0	0	33	5
	A24942	108	8	0	0	0	0	0	0	172	13
	A24950	34	4	0	0	0	0	0	0	289	34
	A24958 + A25449	64	8	0	0	0	0	0	0	152	19
	A24975	3	1	0	0	0	0	0	0	27	9
	A26787	5	2	0	0	0	0	0	0	47	19
	A26796 + A1001698	59	5	0	0	0	0	0	0	383	32
	A26809	10	2	0	0	0	0	0	0	31	6
	A26819	5	2	0	0	0	0	0	0	39	16
	A26845	26	4	0	0	0	0	0	0	129	20
	A26855	14	4	0	0	0	0	0	0	73	21
	A26885	8	2	0	0	0	0	0	0	57	14
	A30656 + A30662 + A30669	37	3	0	0	0	0	0	0	57	5
	A30675	1	1	0	0	0	0	0	0	5	5
	A30681	6	2	0	0	0	0	0	0	16	5
	A30689	19	2	0	0	0	0	0	0	216	23
	A30696	83	7	0	0	0	0	0	0	75	6
	A30706	26	5	0	0	0	0	0	0	368	71
	A30963	16	2	0	0	0	0	0	0	27	3
	A31016	5	1	0	0	0	0	0	0	25	5
	A31055	31	4	0	0	0	0	0	0	161	21
	A31526 + A31533	42	4	0	0	0	0	0	0	98	6
Postholes	A19441	20	4	0	0	0	0	0	0	6	1
	A21964	316	14	0	0	0	0	0	0	45	2
	A24966	9	2	0	0	0	0	0	0	7	2
	A26001	13	3	0	0	0	0	0	0	4	1
	A26062	0	0	0	0	0	0	0	0	0	0

4. Results

The site of Sunnansund was excavated using fine-mesh sieves, which led to the discovery of an area densely packed with fish bone. Once the cultural layer had been removed, a distinct gutter-shaped cut was discovered through the underlying clay (Fig. 4). An explanation for the large quantities of fish bone localized in this one area of the site was then sought.

The gutter was located on the shore of a former lake and was dug into the clay with a slight slope towards the water, where it had been broadened into a deeper pit. On the southern and eastern part of the gutter 32 stakeholes, originating from stakes that had been

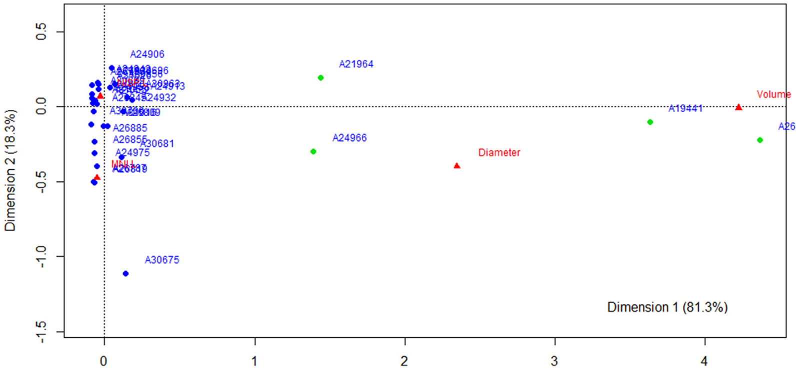

Fig. 5. Correspondence analysis comparing NISP and MNI/L of sifted soil with the diameter and volume of the stakeholes and postholes (marked in red). The postholes are shown in green and the stakeholes in blue. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Table 2
The fish bone content (NISP) of the western, eastern and cleanup (the transition area between the gutter and cultural layer) sections of the gutter and the adjacent stakeholes and postholes.

		Cyprinids *Cyprinidae*	Perch *Perca fluviatilis*	Pike *Esox lucius*	Ruffe *Gymnocephalus cernua*	Eel *Anguilla anguilla*	Burbot *Lota lota*	Pike perch *Sander lucioperca*	Whitefish *Coregonus*	Smelt *Osmerus eperlanus*	Arctic char *Salvelinus alpinus*	Salmonids *Salmonidae*	Indeterminate fish	Total fish bones
Gutter	Western part 2.5 mm	5371	906	350	8	60	33	5	16	3	3	1	2110	8866
	Eastern part 5 mm	307	31	73		2	5						89	507
	Cleanup 2.5 mm	1457	234	119	17	9	11		2	1		1	623	2474
Stakehole	A24452	25	5		1								11	42
	A24906	31											9	40
	A24913	32	9	3	1								8	53
	A24924	37	2										13	52
	A24932	19	1	2									7	29
	A24942	89	11	7	1								37	145
	A24950	21	11	1			1						14	48
	A24958 + A25449	52	7	4		1							21	85
	A24966	8	1										2	11
	A24975	3												3
	A26787	4	1										1	6
	A26796 + A1001698	54	1	3		1							11	70
	A26809	9	1											10
	A26819	2	3										8	13
	A26845	20	4			1	1						5	31
	A26855	10	2	1	1								17	31
	A26885	7	1										4	12
	A30656 + A30662 + A30669	30	5	2										37
	A30675	1												1
	A30681	4	2										3	9
	A30689	18	1										7	26
	A30696	59	13	7		2	2						24	107
	A30706	23	1	1		1							11	37
	A31016	5											5	10
	A31055	28	2	1									12	43
	A31526 + A31533	33	8	1									15	57
Posthole	A19441	14	3		2				1				5	25
	A21964	267	34	9	3	2	1						93	409
	A26001	11	2											
	A30963	15	1											
	Total amount	8051	1302	584	34	79	54	5	19	4	3	2	3165	13302

Table 3
The quantity and weight of mammal and bird bone found within the gutter. Mice and voles were excluded because they were considered to be intrusions of non-anthropogenic origin.

	Species	Body part	Quantity	Weight (g)
Western section 2.5 mm	Wild boar *(Sus scrofa)*	Metacarpus 4	1	11.6
	Wild boar *(Sus scrofa)*	Phalanx 1	1	5.5
	Spotted nutcracker (*Nuchifaga caryocatactes*)	Ulna	1	0.13
	Seal (*Phocidae*)	Cranium, pars petrosum	1	0.03
	Seal (*Phocidae*)	Cranium, calvarium	1	0.23
Eastern section 5 mm	Ringed seal (*Pusa hispida*)	Humerus, proximal	1	0.74
	Crow (*Corvus corone*)	Tarsometatarsus, distal	1	0.2
	Roe deer (*Capreolus capreolus*)	Metacarpus, proximal	1	0.6
Cleanup 2.5 mm	Seal (*Phocidae*)	Cranium, pars petrosum	12	2.1
	Seal (*Phocidae*)	Costae, epiphysis	1	0.1
	Grey seal (*Halichoerus grypus*)	Phalanx 1	1	0.8
	Common merganser (*Mergus merganser*)	Furcula	1	0.12
	Common merganser (*Mergus merganser*)	Tibiotarsus	1	0.98
Stakehole A24942	Squirrel (*Sciurus vulgaris*)	Radius, proximal	1	0.06
Posthole A21964	Seal (*Phocidae*)	Cranium, pars petrosum	1	5.5

Fig. 6. Articulated metacarpal 4 and phalanx 1 of a wild boar with many distinct cutmarks. Photo: Adam Boethius.

inserted into the ground, were located on the rim of the gutter or slightly outside the outer edge. Five larger postholes also surrounded the gutter (Fig. 3). The fills of the smaller stakeholes were identical to that of the gutter, while the larger postholes did not show the same high fish bone densities as seen in the gutter and stakeholes (see Table 1 and Fig. 5).

In addition, large amounts of bark were detected in the area stratigraphically above the gutter, and remains of degraded plant fibers were found on parts of the clay wall within the gutter. In total, 9025 fish bones were identified from the gutter and 1128 fish bones from the postholes and stakeholes (Table 2). In addition, 24 bird and mammal bones were identified in the gutter and two mammal bones identified in the postholes and stakeholes (Table 3).

As shown in Table 2, there were large discrepancies in the fish bone abundance between the western sections, where the NISP was 6756, and the eastern section, where only 418 fish bones were identified. Because the excavation of the gutter was divided so that both the western and eastern sections covered all areas of the gutter (Fig. 3), the differences in NISP values reflected the method of retrieval. Using a 5-mm sieve instead of a 2.5-mm sieve appeared to reduce fish bone recovery by 94%. Even though four 1-L macro samples were taken from the eastern part of the feature and that soil was not included in the analysis, the results highlight the need to apply fine-meshed sieves in areas with large quantities of fish bone in order to maximize retrieval of small fish bones, and regular soil checks should be taken in all areas of an excavation.

The relatively low quantities of mammal and bird bone in the gutter differed from other areas of the site. The bird and rodent fragments found in the gutter could have been natural or chance deposits; however, the phalange and many skull fragments from seal and the articulated wild boar metacarpal and phalange with modification marks (Fig. 6) suggested a functional explanation.

The fish bone content in and around the gutter differed from other areas of the site. Spatial analysis of the frequency of fish species across four contemporaneous sections of the cultural layer was used to compare individual species within the gutter using a correspondence analysis (Fig. 7). There was more fish bone in and around the gutter compared with elsewhere on the site, and the

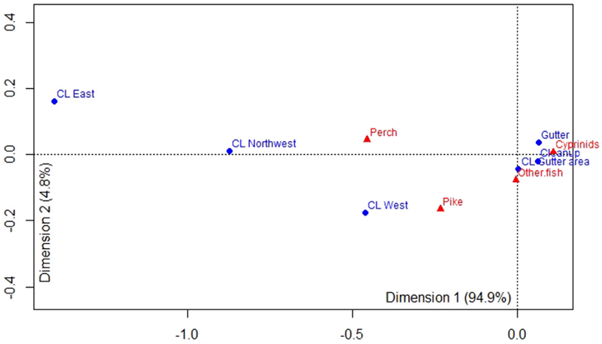

Fig. 7. Correspondence analysis showing the species distribution between different areas of the oldest cultural layer (CL) on the settlement and the gutter. Only areas sieved with a 2.5-mm sieve are included. The fish bone content in areas around the gutter (CL Gutter area, Cleanup and Gutter) is separated from the other parts of the site because it is dominated by cyprinids (roach); elsewhere perch and pike dominate.

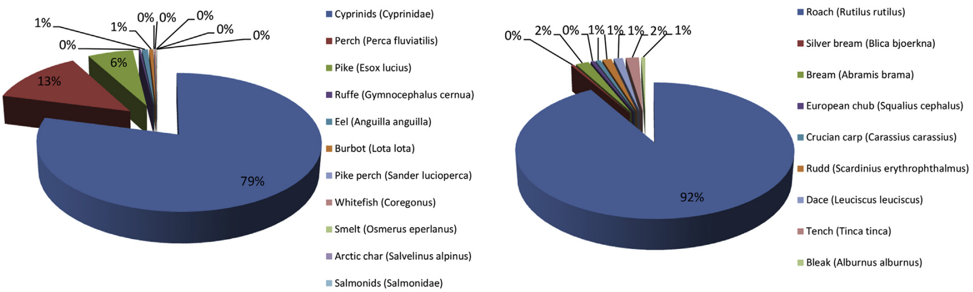

Fig. 8. Fish species distribution in the gutter based on NISP (left) $n = 9025$, and the distribution of cyprinids (right) based on the number of cyprinid bones identified to species level $n = 720$.

Fig. 9. A pike caudal vertebra with a collapsed vertebral body (right) compared with a normal modern pike caudal vertebra (left). Photo: Adam Boethius.

gutter assemblage was dominated by cyprinids, mainly roach (*Rutilus rutilus*) (Fig. 8), whereas perch (*Perca fluviatilis*) and pike (*Esox lucius*) were more abundant elsewhere within the settlement.

The analysis of the fish bones also revealed a pattern in the presence of collapsed caudal vertebral bodies from pike (Fig. 9), indicating that the fish vertebrae had been subjected to acid (Butler and Schroeder, 1998). This condition was noted on 20% of the pike caudal vertebrae (n = 38) and on a few pre-caudal vertebrae (n = 5) that were found in the gutter. This was not seen on the pike from other parts of the settlement, and no other species displayed the condition, either within or outside the gutter area.

5. Discussion

The frequency of species in the gutter area compared with the rest of the site is suggestive of processing taking place. Cyprinids (roach) represented around 80% of the fish found within the gutter, while perch and pike dominated the assemblages from elsewhere within the excavated area. Roach is a small boney fish that is hard to consume, so some form of processing to soften the bones and make them more edible and/or removable is desirable. A possible bone softening process by acidification is suggested by the collapsed pike vertebral bodies within the gutter. While the reason why only pike vertebrae were subjected to the disfiguration is not completely understood, the fact that this phenomenon was only noted in the gutter area suggests that pike vertebrae are somewhat structurally weaker than other fish vertebrae and therefore more prone to displaying this condition under certain circumstances. As acids have a destructive and softening effect on bones (Ishikawa et al., 1989), an acidification process could have been used to prepare and conserve the fish. In Japan there are traditional methods for processing small bony fish that use vinegar to create an acidic environment that softens the bones and makes them edible (Ishikawa et al., 1989). In the absence of vinegar, it is possible to create an acidic environment through fermentation, which (importantly) also preserves the fish. Fermentation can be used as storage technique on a large-scale (Savadogo, 2012) because it is possible to ferment large quantities of food products without the need for a great deal of initial preparation before the preservation process is started. Given the date of the settlement containing the gutter, clearly a closer examination of this tentative interpretation is warranted. Especially since one might argue that it is impossible to identify the original purpose of a feature without parallels in the archaeological record or that other explanations for the evidence hold equal merit; e.g. the observed patterns indicate a special type of deposition for fish waste, that it represents the content of a seal stomach or a ritual practice with unknown purpose.

Fermentation is a skilled technique (Stopp, 2002). Modern methods of food fermentation use salt in combination with the fermentation enzyme *Lactobacilli* to prevent spoilage and the growth of pathogenic microorganisms, and provide a means of preservation that requires little attention (Leroy and De Vuyst, 2004). However, such methods would not have been available in pre-salt communities. The earliest evidence of fermentation is found in wine-making, dated to around 7400 cal. BP (McGovern et al., 2004), while the first evidence of food fermentation appears to be from Egypt about 6000 cal. BP (Hutkins, 2006). From historical sources, fish fermentation is associated with the Roman fish sauce *garum*, which was popular in the Roman empire 2000 years ago (Corcoran, 1963). It is perhaps because of its association with the Roman culture that fermentation is known to be a highly skilled process and therefore not commonly considered in other contexts. However, traditional circumpolar people, such as the Inuits from Greenland, the Eskimos from the Nunivak and Kodiak islands outside Alaska, the Mackenzie Eskimos in Canada, the Jawina in Kamchatka (Russia), the Turukhansk in Siberia and the Karelians in Finland, commonly ferment food without adding salt, because salt is not a necessary part of the process in colder environments. Understanding that salt is not necessary if other prerequisites are met is therefore a key step in realizing the possibility of finding evidence of fermentation in societies from colder environments long before salt was introduced.

Ethnographic studies of circumpolar people provide further indications that the gutter could have been used for fermenting fish. The most common ethnographic accounts of fermenting fish during the last two centuries, from Alaska, northern Siberia and Kamchatka, are the practice of burying fish in a hole dug through the top soil and into the underlying clay (Behrens, 1860; Lantis, 1946). The construction in Sunnansund is suggestive of this technique, where the gutter becomes visible against the naturally

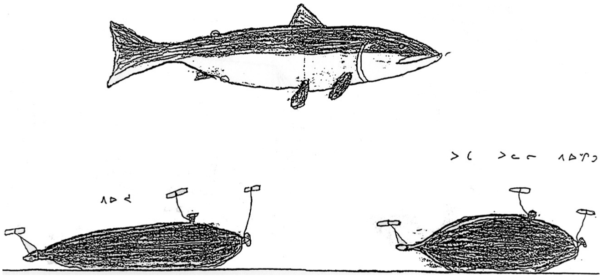

Fig. 10. Illustration of fish fermentation with the aid of seal fat. “Arctic char without their heads and guts can be put into apuurtaq (sealskin storage bag) along with misiraq (liquid seal fat)/ … /. You can even tell between the two puurtaqs. The left one is fish with misiraq and it is not inflated, the right one is full of meat but with no fat in it and it is inflated. If you eat this you would die.” Drawing and caption by Tuumasi Kudluk: Collection, A:46. Drawing used with the courtesy of Avataq Cultural Institute. Drawing also in Stopp (2002).

deposited clay after the cultural layer has been removed. Ethnographic fermentation pits are also located close to water (Kittlitz, 1858), which makes practical sense for both the ethnographic examples and at Sunnansund, because it facilitates minimal transportation of the fish catch.

Another common practice among ethnographic accounts of circumpolar people is the use of animal skins when fermenting food products. This is documented in Greenland and Canada, where the Polar Eskimos and Canadian Inuits, respectively, commonly put birds and fish in airtight sealskins and leave them to ferment for a few months before consumption (Johansen, 2013; Freuchen and Freuchen, 1961; Stopp, 2002). The grey seal phalange and possibly the seal skull fragments found in the gutter could indicate the same practice at Sunnansund. The same is true for the wild boar metacarpal and phalange found within the gutter: both these bones display modification marks (Fig. 6) possibly related to the use of a wild boar skin, which could, similar to seal skin, have been used in the context of anaerobic fermentation.

This type of anaerobic fish fermentation would have needed extra fat or blubber to prevent the development of botulism bacteria (*Clostridium botulinum)* (Stopp, 2002). The many seal skull fragments present in the gutter could represent the source of that extra fat, perhaps being retained accidentally when fatty seal brain was added to the fermentation. Seal blubber is another possible source of fat for safe fermentation (Fig. 10); while it cannot be identified in an archeological context, its use is often seen in ethnographic accounts (Stopp, 2002).

From both northern Canada, Finland and Kamchatka, there are accounts of fermentation pits being covered to prevent scavenging animals from getting at the fish (Jochelson, Unpublished typescript of MS, Manninen, 1932; Stefansson, 1914). In the case of Sunnansund this could be the reason for the larger postholes surrounding the entire gutter construction. The low fish bone frequency in the postholes compared with the stakeholes and gutter suggests that there was a more or less permanent enclosure present, which could have served to keep scavenging animals away from the fermenting food, while the gutter and the smaller stakes could be used and reused within the enclosed compound. The reuse of the gutter is another indication that it could have been used to ferment fish. The microclimate of a fermentation batch is essential for good results: in modern fermentation processes, a lactic acid bacteria (LAB) is commonly added to each batch to ensure a good fermentation. Bacteria could not be added artificially more than 9000 years ago, but the earliest forms of fermentation could take advantage of naturally occurring bacteria in the surrounding environment to produce a spontaneous fermentation (Leroy and De Vuyst, 2004). Traditional fermentation techniques use ‘back-slopping’ to speed up the fermentation process and ensure a good result: a small amount of a previously successfully fermented product is added to the next fermentation batch, so introducing beneficial LAB (Leroy and De Vuyst, 2004). Back-slopping is indicated at the fermentation gutter from Sunnansund, by the identical contents of the gutter and the many stakeholes. A wild boar skin containing the fermenting fish, represented by the modified and articulating wild boar metacarpal and phalanx, and/or a seal skin, indicated by the grey seal phalange and possibly the seal skull fragments, could have been attached to stakes and stretched over the gutter. This would have allowed air to circulate underneath the fermenting fish, a practice seen among the Greenland Eskimos (Birket-Smith, 1929), albeit not in connection with the use of skins to encase the fermenting batch as suggested at Sunnansund. When the fermentation process was finished, the stakes could be retracted and the meat removed from the fish, and the bones dumped back into the gutter. When the gutter was to be used next, the contents could be cleaned out and the previous stakeholes filled with the gutter contents, thus preserving the microclimate with beneficial bacteria. The archeological contents of the gutter therefore could represent the bones from the last fermentation batch carried out there, and the possibly conscious decision to abandon the fermentation facility. The latter interpretation is reinforced by the deposition of a

Fig. 11. A slotted bone knife (111 × 14 mm) decorated with the skeleton of a fish and found in the cultural layer stratigraphically above the fermentation gutter. Photo: Staffan Hyll, SHMM.

Fig. 12. Three of the four fetal bones from Sunnansund. From left: modern roe deer scapula, archaeological roe deer scapula, archaeological grey seal coxae bone (ischium), archaeological ringed seal ulna. Photo: Adam Boethius.

slotted bone knife, decorated with a fish skeleton, on top of the gutter (Fig. 11): it could have been placed there to seal or close the use of the construction.

Further ethnographic analogies can be drawn from both the Karelians in Finland and the Yakuts in Siberia, who cover and/or line their fermentation pits with bark (Manninen, 1932; Eidlitz, 1969). At Sunnansund, a bark layer covered and surrounded the gutter feature but was not present in any other area of the site. Bark acid helps the fermentation process and functions as a starter, much like today when acid enzymes are added to a fermenting batch in order to reduce fermentation time and improve the quality of the end product (Lindner et al., 2013). Bark also serves to initiate a 'real' fermentation process rather than a putrefaction process (Beller, 1993), which would have a neutral pH level instead of the acidic environment needed to ensure safe fermentation (Hauschild and Gauvreau, 1985).

There are also further similarities with the Karelians, who dig their pits in a funnel-shaped fashion, similar to the shape of the gutter found at Sunnansund. Furthermore, there are accounts of people from Kamchatka and Alaska dressing their fermentation pits with grass (Eidlitz, 1969; Beller, 1993), which could explain the degraded plant fibers found on parts of the walls in the gutter from Sunnansund.

In the cultural layer just outside the gutter, four different types of fetal bone were identified (Fig. 12) that could also have a functional explanation. Fetal vernix (the grease covering the skin of a fetus) is antiseptic (Marchini et al., 2002; Yoshio et al., 2003) and, as fetal bones were only identified in the gutter area of the site, their presence could be related to fermentation activities. Although there are no ethnographic accounts of vernix being used in a fermentation processes, its unique properties and the fact that fetal bones were only found next to the gutter (Fig. 13) could indicate that fetuses were used to control or stop the process when sufficient fermentation had been achieved. Being able to stop an ongoing fermentation process is important, as demonstrated by ethnographic accounts from the Inupiat Inuit from Alaska, who mention that it is important to stop the fermentation process in time as it "otherwise will be too strong" and consequently "only good for the dogs" (Katz, 2012). In these accounts fermentation is stopped by letting the fish freeze. However, if the fermentation was carried out

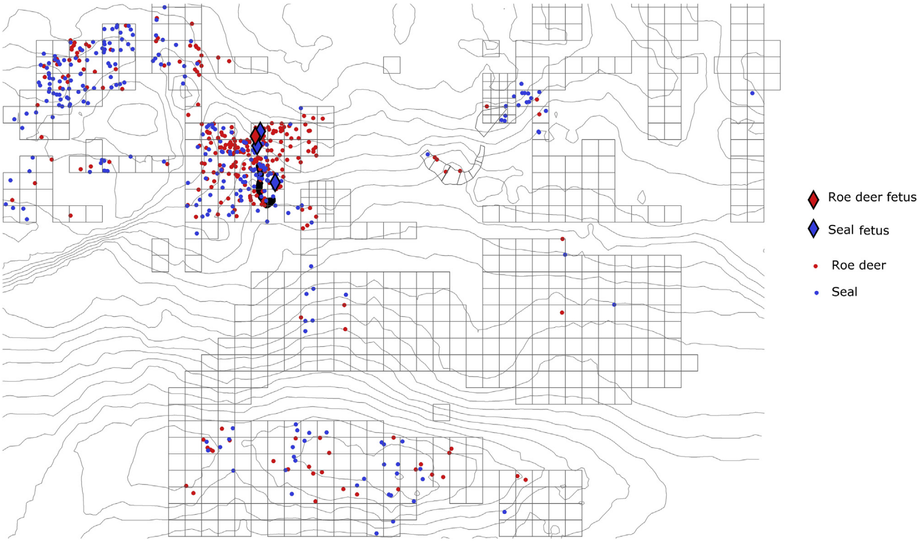

Fig. 13. A plan of the excavated area at Sunnansund. The squares indicate excavated units in the cultural layers; red dots, roe deer bone; blue dots, seal bone; red diamond, roe deer fetal bone; blue diamond, seal fetal bone. The black shape of the gutter is visible underneath the colored shapes on the left side of the diagram. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

in late winter/early spring it would not be possible to freeze the fermenting fish, and so the addition of antiseptic fetus vernix is a plausible suggestion.

However, when fermenting fish without using salt, temperature is probably the most important factor for keeping the fermentation process under control and preventing botulism bacteria from forming (Beller, 1993). The need for a constantly cool environment is an intriguing part of the interpretation, because the area of southern Sweden where Sunnansund is located would, under normal circumstances, not be considered cold enough to ensure a safe fermentation process, based on the fact that no modern ethnographic groups practice non-salted fish fermentation in similar climates. The estimated average temperature during the winter in this area was about 1.5 °C colder than today during the Boreal period (Davis et al., 2003). However, it would still have been warmer than in areas where ethnographic evidence indicates that fermentation has been practiced without adding salt (Eidlitz, 1969). But there have been global cold events, and one of these corresponds with the occupation of the older phase of Sunnansund and matches the dates from the gutter (Fig. 2). During this '9.2 event' a large volume of freshwater was released into the Atlantic Ocean (Fleitmann et al., 2008), temporarily lowering the effect of the Atlantic thermohaline circulation, and leading to a colder climate in the Northern Hemisphere. The effect of this event probably only lasted between 40 and 100 years (Fleitmann et al., 2008; Rasmussen et al., 2007), but the resulting drop in temperature would have put Sunnansund within the range of ethnographic evidence of non-saline fermentation. This event may also be reflected in the Sunnansund bone assemblage by the presence of newborn and fetal ringed seal (*Pusa hispida*) (Boethius, forthcoming). Ringed seals nest and give birth within snow caves on the ice (Härkönen, 2011): these bones therefore provide evidence that gestating ringed seals were hunted on the ice on the coast of south-eastern Sweden. This could only have occurred if the temperatures were lower than usually estimated (Antonsson, 2006; Davis et al., 2003); because ringed seals normally breed in the northern part of the Baltic (Schmölcke, 2008).

When previously unidentified archaeological features are exposed, it is often problematic to interpret them and recognize what they represent; because one observation might often be interpreted in many ways. Indeed, some of the observations from Sunnansund can be considered true for alternative interpretations; the disfiguration of pike vertebrae could have occurred within the acidic environment of a seal stomach and large amount of fish bones accumulated in one area could be considered a waste pit to dispose strong smelling fish leftovers. In addition, there is always the tantalizing interpretation of hidden rituals. However, all other interpretations exempt the gutter being used to ferment fish only fit with one or a couple of contextual observations and ethnographic accounts of ritual behavior do not correspond with the evidence from the Sunnansund gutter. Thereby, given the archaeological context of this special feature, its varied pieces of contextual information, the dates corresponding with a global cold event and considering the many and varied circumpolar ethnographic parallels, the most likely explanation is that the construction was used to ferment fish.

6. Conclusions

The conservation of large quantities of fish through fermentation has been demonstrated at the site of Norje Sunnansund. The implications of the process of fermentation being used more than 9000 years ago alter our perception of Early Mesolithic foraging societies in a fundamental way. Being able to adapt to changing environmental conditions, as seen with fermentation being carried out at relative low latitudes during a cold event, demonstrates an environmental responsiveness as well as a range of survival strategies and technological knowledge. Even though it is possible that this technology was invented locally, it is more likely that the skill came from more northern areas, where knowledge of how to use this type of preservation and storage system and utilize the cold climate to ferment fish without the products going bad, could have existed throughout the Holocene, without a break caused by the ongoing global warming. Therefore, the presence of a fish fermentation facility in southern Scandinavia implies large contact networks and/or movement to other regions. This contact is supported by evidence of diverse stone- and bone-working technologies being applied at Sunnansund (David and Kjällquist, in press), which implies distant contacts, and by diverse strontium signals in the tooth enamel from the human remains found at the site, which imply different origins for some of the inhabitants (Kjällquist and Price, forthcoming). Furthermore, successful fermentation is a skillful way of preparing and preserving food, and confers a substantial advantage on the society practicing it. Being able conserve food products over an extended time period enables the practice of delayed-return subsistence, which implies a high degree of sedentism. Long-term food storage is also a requirement for societal evolution, resulting in an elaborate community (Rowley-Conwy, 1983; Rowley-Conwy and Zvelebil, 1989; Cunningham, 2011), and has consequences for how Mesolithic demographics are modeled, with the possibility of larger communities with higher birth rates, because access to a stored surplus is often connected with a population increase (Kuijt, 2008). The evidence of large-scale food preservation and storage being utilized in the Early Mesolithic means larger populations could have been present than has previously been considered in early foraging contexts.

From a global perspective, it has been demonstrated that people living at higher latitudes rely more on animal protein than on gathering plants, and the higher the latitude the more dominant fish is in the diet (Marlowe, 2005). It has been calculated that the amount of fish caught at Sunnansund was enough to support a considerable number of people living at the location for a long period of time (Boethius, in press), which together with cervid hunting strategies focusing on fully grown young adults (Boethius, forthcoming), implies a sizable community with a sophisticated lifestyle. In many ways this equals the contemporaneous ongoing Neolithic revolution in the Middle East. The difference lies in the approach to the environment and the source of food: whereas the early farmers practiced husbandry of domesticated animals and harvested crops, the northern foragers harvested the aquatic environment and 'tamed' the water.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jas.2016.01.008.

References

Antonsson, K., 2006. Holocene Climate in Central and Southern Sweden: Quantitative Reconstructions from Fossil Data. Uppsala University, Uppsala.

Behrens, W., 1860. Etnographisk Beskrivelse over Nord Grønland (Copenhagen).

Beller, M., 1993. Botulism in Alaska: a Guide for Physicians and Health Care Providers, 2011 Update. Department of Health and Social Services, Division of Public Health, Section of Epidemiology, State of Alaska.

Birket-Smith, K., 1929. The Caribou Eskimos: Material and Social Life and Their Cultural Position. Gyldendalske Boghandel, Nordisk Forlag, Copenhagen.

Boethius, A., 2016a. Signals of sedentism the use of the environment as evidence of a delayed-return economy in Early Mesolithic south eastern Sweden. J. Nordic Archaeol. Sci. forthcoming.

Boethius, A., 2016b. The use of aquatic resources by Early Mesolithic foragers in southern Scandinavia. In: Persson, P., Skar, B., Breivik, H.M., Riede, F., Jonsson, L. (Eds.), The Early Settlement of Northern Europe – Climate, Human Ecology, and Subsistence. Equinox, Sheffield (in press).

Butler, V.L., Schroeder, R.A., 1998. Do digestive processes leave diagnostic traces on fish bones? J. Archaeol. Sci. 25, 957–971.

Corcoran, T.H., 1963. Roman fish sauces. Class. J. 58, 204–210.

Cunningham, P., 2011. Caching your savings: the use of small-scale storage in European prehistory. J. Anthropol. Archaeol. 30, 135–144.

David, É., Kjällquist, M., 2016. Transmission of the Mesolithic northeastern crafting tradition. The Norje Sunnansund style introduced in the Maglemosian area around 9.3 ka BP. In: Knutsson, K., Knutsson, H., Apel, J., Glørstad, H. (Eds.), The Early Settlement of Northern Europe – Technology and Communication. Equinox, Sheffield (in press).

Davis, B., Brewer, S., Stevenson, A., Guiot, J., 2003. The temperature of Europe during the Holocene reconstructed from pollen data. Quat. Sci. Rev. 22, 1701–1716.

Eidlitz, K., 1969. Food and Emergency Food in the Circumpolar Area. Almqvist & Wiksell, Uppsala.

Fleitmann, D., Mudelsee, M., Burns, S.J., Bradley, R.S., Kramers, J., Matter, A., 2008. Evidence for a widespread climatic anomaly at around 9.2 ka before present. Paleoceanography 23, 1–6.

Freuchen, P., Freuchen, D., 1961. Book of the Eskimos. World Publishing Company, Cleveland.

Hauschild, A., Gauvreau, L., 1985. Food-borne botulism in Canada, 1971–84. Can. Med. Assoc. J. 133, 1141–1146.

Hutkins, R.W., 2006. Microbiology and Technology of Fermented Foods. IFT Press, Chicago.

Härkönen, T., 2011. Klimatförändringar – så påverkas våra sälar. In: Lewander, M., Karlsson, M., Lundberg, K. (Eds.), Havet 2011 Om Miljötillståndet I Våra Havsområden. Havsmiljöinstitutet.

Ingold, T., 1983. The significance of storage in hunting societies. Man 18, 553–571.

Ishikawa, M., Mori, S., Watanabe, H., Sakai, Y., 1989. Softening of fish bone. II. Effect of acetic acid on softening rate and solubilization rate of organic matter from fish bone. J. Food Process. Preserv. 13, 123–132.

Jochelson, W. Unpublished typescript of MS. The Kamchadals. http://www.facultysite.sinanewt.on-rev.com/JochelsonTheKamchadals.pdf.

Johansen, T.B., 2013. Foraging efficiency and small game: the importance of dovekie (Alle alle) in Inughuit subsistence. Anthropozoologica 48, 75–88.

Katz, S.E., 2012. The Art of Fermentation: an In-depth Exploration of Essential Concepts and Processes from Around the World. Chelsea Green Publishing, White River Junction.

Kittlitz, F.H., 1858. Denkwürdigkeiten einer Reise nach dem russischen Amerika, nach Mikronesien und durch Kamtschatka. Kulturstiftung Sibirien, Germany.

Kjällquist, M., Emilsson, A., Boëthius, A., 2016. Norje Sunnansund. Boplatslämningar från tidigmesolitikum och järnålder. Särskild arkeologisk undersökning 2011 och arkeologisk förundersökning 2011 och 2012, Ysane socken, Sölvesborgs kommun. Blekinge museum rapport 2014:10.. Blekinge museum, Karlskrona.

Kjällquist, M., Price, T.D., 2016. Isotopic Proveniencing of Mesolithic Human Remains from Norje Sunnansund, Sweden forthcoming.

Kuijt, I., 2008. Demography and storage systems during the southern Levantine Neolithic demographic transition. In: Bocquet-Appel, J.-P., Bar-Yosef, O. (Eds.), The Neolithic Demographic Transition and its Consequences. Springer, Dordrecht.

Lagerås, P., Broström, A., Svensson, N.-O., 2016. Insamling av ätliga växter och ved under mesolitikum. En diskussion baserad på makrofossil och träkol från västra Blekinge. In: Rudebeck, E., Anglert, M. (Eds.), E22 Project, Sölve – Stensnäs, Project Synthesis forthcoming.

Lantis, M., 1946. The social culture of the Nunivak Eskimo. Trans. Am. Philosophical Soc. 35, 153–323.

Leroy, F., De Vuyst, L., 2004. Lactic acid bacteria as functional starter cultures for the food fermentation industry. Trends Food Sci. Technol. 15, 67–78.

Lindner, J.D.D., Penna, A.L.B., Demiate, I.M., Yamaguishi, C.T., Prado, M.R.M., Parada, J.L., 2013. Fermented foods and human health benefits of fermented functional foods. In: Soccol, C.R., Pandey, A., Larroche, C. (Eds.), Fermentation Processes Engineering in the Food Industry. CRC Press, Boca Raton.

Manninen, I., 1932. Die Finnisch-ugrischen Völker. Harrassowitz, Leipzig.

Marchini, G., Lindow, S., Brismar, H., Ståbi, B., Berggren, V., Ulfgren, A.K., Lonne-Rahm, S., Agerberth, B., Gudmundsson, G., 2002. The newborn infant is protected by an innate antimicrobial barrier: peptide antibiotics are present in the skin and vernix caseosa. Br. J. Dermatol. 147, 1127–1134.

Marlowe, F.W., 2005. Hunter-gatherers and human evolution. Evol. Anthropol. Issues News, Rev. 14, 54–67.

McGovern, P.E., Zhang, J., Tang, J., Zhang, Z., Hall, G.R., Moreau, R.A., Nuñez, A., Butrym, E.D., Richards, M.P., Wang, C.-s, 2004. Fermented beverages of pre-and proto-historic China. Proc. Natl. Acad. Sci. U. S. A. 101, 17593–17598.

Milner, N., 2009. Mesolithic consumption practices: food for thought. J. Nordic. Archaeol. Sci. 49–63.

Nenadic, O., Greenacre, M., 2007. Correspondence analysis in R, with two-and three-dimensional graphics: the ca package. J. Stat. Softw. 20, 1–13.

Rasmussen, S.O., Vinther, B.M., Clausen, H.B., Andersen, K.K., 2007. Early Holocene climate oscillations recorded in three Greenland ice cores. Quat. Sci. Rev. 26, 1907–1914.

Rowley-Conwy, P., 1983. Sedentary hunters: the Ertebølle example. In: Bailey, G.N. (Ed.), Hunter-gatherer Economy in Prehistory. Cambridge University Press, Cambridge.

Rowley-Conwy, P., Zvelebil, M., 1989. Saving it for later: storage by prehistoric hunter-gatherers in Europe. In: Halstead, P., O'Shea, J. (Eds.), Bad Year Economics: Cultural Responses to Risk and Uncertainty. Cambridge University Press, Cambridge.

Savadogo, A., 2012. The role of fermentation in the elimination of harmful components present in food raw materials. In: Mehta, B.M., Kamal-Eldin, A., Iwanski, R.Z. (Eds.), Fermentation Effects on Food Properties. CRC Press, Boca Raton.

Schmölcke, U., 2008. Holocene environmental changes and the seal (Phocidae) fauna of the Baltic sea: coming, going and staying. Mammal. Rev. 38, 231–246.

Seifert, T., Tauber, F., Kayser, B., 2001. A high resolution spherical grid topography of the Baltic Sea–2nd edition. Poster# 147. Online. In: Baltic Sea Science Congress, Stockholm 25–29. November 2001. www.iowarnemuende.de/iowtopo.

Stefansson, V., 1914. The Stefansson-andersson Arctic Expedition of the America Museum. Preliminary ethnological report. Order of the Trustees, New York.

Stopp, M.P., 2002. Ethnohistoric analogues for storage as an adaptive strategy in northeastern subarctic prehistory. J. Anthropol. Archaeol. 21, 301–328.

Yoshio, H., Tollin, M., Gudmundsson, G.H., Lagercrantz, H., Jörnvall, H., Marchini, G., Agerberth, B., 2003. Antimicrobial polypeptides of human vernix caseosa and amniotic fluid: implications for newborn innate defense. Pediatr. Res. 53, 211–216.

Paper II

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Signals of sedentism: Faunal exploitation as evidence of a delayed-return economy at Norje Sunnansund, an Early Mesolithic site in south-eastern Sweden

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ABSTRACT

Delayed-return foraging strategies connected with a sedentary lifestyle are known from Late Mesolithic Scandinavian settlements. However, recent evidence from the archaeological site of Norje Sunnansund, in south-eastern Sweden, indicates the presence of sedentism from the Early Mesolithic. By analyzing the faunal assemblage from Norje Sunnansund, patterns of delayed-return strategies were examined for five categories of faunal exploitation/interaction: seal hunting, fishing, ungulate hunting, opportunistic hunting and rodent intrusions. The evidence suggests selective hunting strategies, large catches of fish and all year round seasonality indicators as well as evidence of commensal behavior in non-typical commensal species. The data were related to ethnographic accounts and sedentary foraging societies' modes of subsistence. The evidence suggests an expanding, sedentary, aquatically dependent Early Mesolithic foraging lifestyle in southern Scandinavia, which, it is argued, came to dominate the mode of subsistence, implying larger settlements and a larger prevalent population. This process may have been going on for millennia prior to the rise of the Late Mesolithic Ertebølle culture, implying much larger Late Mesolithic populations than previously realized, perhaps comparable with the native cultures of the north-west coast of America.

1. Introduction

A delayed-return subsistence strategy has often been connected with complex societies (Arnold, 1996; Bender, 1978; Price and Brown, 1985) and sedentary lifestyles[1] and was originally considered to be one of the traits associated with agriculture and the Neolithic revolution (Meillassoux, 1973). This led to its emphasis in discussions of the basic subsistence strategies of Late Pleistocene and Early Holocene foraging societies and what separates them from the agricultural societies of the Neolithic period (Hole, 1984). In Early Mesolithic Europe, humans have often been seen as mobile groups of people living directly off the land, optimally exploiting their environment (Jochim, 2011) and, in doing so, not creating the large surpluses that would facilitate a delayed-return lifestyle (Sahlins, 1972). While this might be true in some areas and for some societies, the Early Mesolithic period displays great cultural diversity (Jordan and Zvelebil, 2009; Warren, 2014) and is often defined as a period of great environmental change (Cummings, 2014). Increasing global temperatures (Lowe and Walker, 2015), reforestation of vast land areas previously covered by large grass steppes (Tarasov et al., 2012) and a series of megafaunal extinctions in the Late Pleistocene (Elias and Schreve, 2007) led to a diversification of human subsistence strategies and a broad spectrum revolution (Flannery, 1969; Zeder, 2012).

Although there are many difficulties in identifying sedentism and delayed-return economies in prehistoric foraging societies, because of problems in interpreting the archaeological record (Rowley-Conwy, 2001), diverse evidence from Paleolithic and Early Mesolithic Europe and northern Asia has provided many sources of data that can be used to establish a baseline for interpreting Early Mesolithic Scandinavia. For example, (semi-)sedentary settlements are suggested at exceptional Upper Paleolithic sites such as Dolní Věstonice (Klima, 1962), Kostenki-Borshevo (Klein, 1969) and several other Russian sites (Soffer, 1985), where numerous storage

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[1] The use of the term sedentism follows the definition given by Susan Kent, when she argues that sedentism should be viewed as a group of people spending most of the year at one locus even if 'at other times during the year the group leaves, returning to the community after short, often seasonal, absences' (Kent, 1989). Thereby, and even though the term implies a stationary lifestyle; sedentism, as defined, includes a wide number of mobility strategies, which can vary throughout the years and include different constellations within a group of people (Kelly, 1992).

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pits have been found (Soffer, 1985). There are also Upper Paleolithic examples of social stratification, with some individuals displaying extraordinary riches, implying the presence of an elite, such as the three burials from Sungir in Russia (Hayden, 2014). However, even though rich burials are known from the Paleolithic, it is not until well into the Mesolithic period that evidence of large cemeteries, such as at Olenii Ostrov, Zvejnieki, Vedbæk-Bøgebakken and Skateholm, starts to emerge (Albrethsen and Brinch Petersen, 1976; Larsson, 1988; Nilsson Stutz, 2014), providing good examples of social complexity. Because of the complexity and size of the cemeteries and the many large settlements known from the Scandinavian Ertebølle culture, which display a wide array of traits related to complex societies, social stratification, high aquatic dependency and a sedentary lifestyle (Nilsson Stutz, 2003; Rowley-Conwy, 1983; Warren, 2014), the Late Mesolithic Ertebølle culture of southern Scandinavia has been compared with the complex foragers of the American north-west coast (Tilley, 1996), although others have disputed these claims (Cummings, 2013). However, what if there was a delayed-return economy in the Scandinavian Early Mesolithic period, thousands of years prior to the emergence of the Ertebølle culture? Would this require a redefinition of the period prior to the transition to farming in the area, and can a long (and strong) tradition of complex, sedentary, aquatically reliant societies explain why the transition to agriculture was delayed for more than a thousand years before it was fully adopted in Scandinavia?

It is generally considered that sedentism can emerge where the energy costs of moving are higher than when staying put (Kelly, 2013:113) and can be narrowed down to situations ‘pushing’ foragers away from mobility or ‘pulling’ them towards a sedentary life (Brown, 1985). This can occur when increasing population pressures lead to a shortage of available land and, as a result, higher energy costs for moving around or ‘removing’ a competitive neighboring group of people (Binford, 2001), when it is more energy efficient to control and use abundant resource extraction points (Binford, 1968; Harris, 1977), or because moving costs exceed the costs of staying (Kelly, 1983:292). Regardless of the reason, in order to live in a sedentary manner over an extended time period, it is vital that the area can support occupation in terms of fulfilling the populations’ dietary requirements throughout the year, which is why sedentary societies are located in ecotone environments (Sutton, 2016) where diverse resources can be used as a risk-reducing strategy (Rowley-Conwy and Zvelebil, 1989). Sedentary societies are also associated with delayed-return subsistence strategies and practice storing to cope with seasonal fluctuations (Kelly, 2013:20, 103), and are often primarily dependent on reliable aquatic resources (Binford, 2001:398). Furthermore, as the pressure on the surrounding landscape increases when people are stationary and not actively moving out of an area, as resources start to become depleted (Kelly, 2013:253) it is reasonable to suggest that steps will be taken to ensure that key resources are sustained. Indeed, there is evidence of foraging behavior remodeling and modifying the natural environment from the Mesolithic period, with the control and management of essential plants (such as fruit trees, hazel and oak) enabling a harvest at a later point in time (Bos and Urz, 2003; Holst, 2010; Huntley, 1993; Mason, 2000). Technological innovations are also important for sedentary lifestyles, and the creation of mass-harvesting technologies can increase the nutritional input from a given area and, therefore, reduce the risk caused by low mobility, especially if applied to reliable aquatic resources (Binford, 2001:391-99; Kelly, 2013:127-30). For example, the creation of large fish traps allows the environment to be exploited further and can be considered a delayed-return practice (Rowley-Conwy, 2001; Woodburn, 1980). This type of mass-harvesting technology has been found in southern Scandinavia from the Early Mesolithic onwards (Hadevik et al., 2008; Hansson et al., 2016; Karsten et al., 2003; Pedersen, 1995) and it stands to reason that if a society is sedentary it should be possible to identify different types of activity taken to ensure continued occupation in the area. Consequently, the aim of this study was to examine the evidence for a delayed-return economy during the Scandinavian Early Mesolithic period and investigate how any environmental adaptations and subsistence strategies related to the prerequisites for a sedentary lifestyle. The faunal assemblage from Norje Sunnansund, the only known Early Mesolithic Scandinavian east-coast site, was used to facilitate the study, in combination with archaeological, paleoenvironmental, ethnographic and ecological approaches. The questions addressed were: can we identify the presumably many active strategies adopted to ensure survival with a sedentary lifestyle, and can circumstantial evidence provide information about sedentism?

2. Materials and methods

The archaeological settlement site of Norje Sunnansund is located in south-eastern Sweden (Fig. 1, left) and has been dated to about 9600–8600 cal. BP (Kjällquist et al., 2016), although the actual use of the settlement should be considered shorter, due to a combination of poorly preserved carbon in the dated bones, especially during the younger phase, and a contemporary radiocarbon calibration plateau, which both increased the dating spans. At the time of occupation, the site was located on the shores of a shallow lake (Vesan), next to a stream leading out to the Baltic basin, which was located 2 km away (Fig. 1, right). The settlement was surrounded by a forest dominated by hazel and pine trees, and in the distance across Vesan the low mountain ridge of Ryssberget stretched for about 20 km. The site mainly contained three cultural layers, representing two separate phases and one significant land feature, a fish fermentation pit surrounded by postholes and stakeholes (Boethius, 2016). Because of significantly poorer preservation in the more recent phase compared with the older phase, it was difficult to date the younger phase properly and the more fragile organic material had degenerated and disintegrated. Even though the settlement was clearly occupied during two separate phases, demarcated by a flooding event, it was impossible to establish how long the site had been flooded for. Furthermore, the content of the different layers appeared on occasions to have been mixed during the occupation of the site. Furthermore, a third layer of water-deposited bones and artifacts derived from both phases could not be temporally separated, which also applies to the bones from the preliminary excavation. However, because the site was completely abandoned at around 8600 cal. BP and covered by the Littorina transgression (Andrén et al., 2011), there were no later intrusions into the cultural layers. Therefore, this study treats the whole Norje Sunnansund site as a single entity and all quantifications and interpretations are based on the entire assemblage. For specific information regarding the separate phases of the site see appendix (Tables A1-A3), for discussions regarding the different phases see Kjällquist et al. (2016), and for further discussions regarding the fish bone material during the oldest phase see Boethius (2016, 2017b). The interpretations presented here are based mainly on the osteological analysis of the site's faunal assemblage. All the mammal and bird bones found at the excavation were analyzed, but only about 13% of the recovered fish bones. Combining all the phases and layers resulted in an assemblage of 1940 mammal bones, 106 bird bones and 16,180 fish bones (Tables A1-A3), which were identified to species level or, where this was not possible, to family level.

The bone material was analyzed with the aid of the reference collections at the National Historical Museums in Lund, at the Department of Historical Osteology, Lund University, Sweden, and the Zoological Museum, Copenhagen University, Denmark. The quantifications were based on number of identified specimens

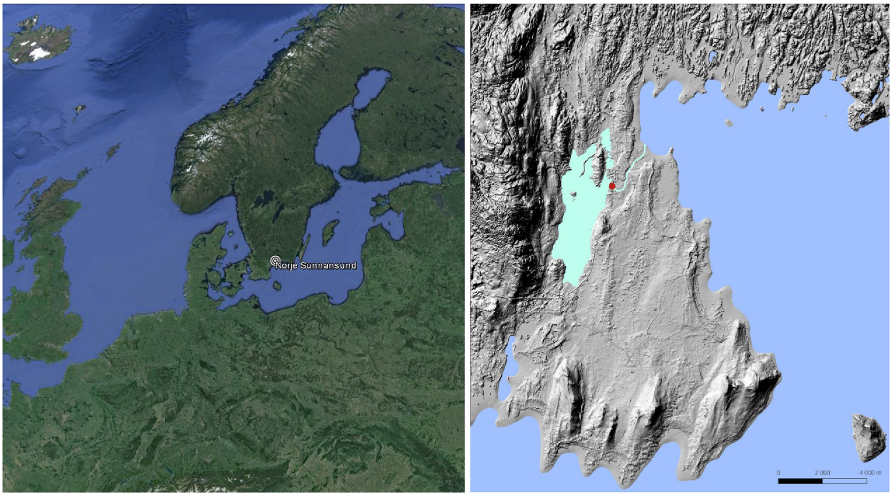

Fig. 1. A map of the area surrounding Norje Sunnansund around 9200 cal. BP. The map is based on a terrain model with 5-m resolution and LIDAR data; topographic information came from the Swedish Land Survey road map [© Lantmäteriet i2012/892] and Swedish Geological Survey marine geological map lowtopo2 (Seifert et al., 2001). Map by N.-O. Svensson, Kristianstad University. Picture on the left from Google Earth.

(NISP). The minimum number of individuals (MNI) have also been derived, by calculating overlapping parts of the most frequently occurring skeletal element and without considerations to age differences, although MNI has not been used beyond being reported (Tables A1-A3).

The element distribution pattern has been examined on animals hunted for fur by dividing the skeletal elements of the body into four regions based on ethnographic dismembering and butchering patterns (Binford, 1981). These are: *cranium*—skull, mandible, and loose teeth; *limb bones*—scapula, humerus, radius, ulna, femur, tibia, and fibula; *body core*—ribs, vertebrae, and pelvis; and *distal extremities*—carpals, tarsals, metapodials, and phalanges.

Age determinations were based on epiphyseal fusion, where the bones represented in each epiphyseal closing stage is illustrated as the percentage of fused/unfused bones in order to derive a kill-off pattern, and osteometrics together with bone texture to identify juveniles (Table 1). Kill-off patterns based on the epiphyseal fusion of different age groups are commonly applied in zooarchaeological studies (O'Connor, 1982), where the frequency of fused epiphyses in each age category represents animals killed at older ages and can be used to construct survivorship curves. Thereby, the age profiles consist of a *Younger than:* category, which is based on the percentage of unfused epiphysis in each age category, and in the youngest age category the addition of bones where size and texture on an individual bone indicates a newly born. The *Older than:* age category is based on the number of fused epiphyses from bones in each age category. Thereby, *Younger than:* equals the percentage of animals not surviving the age group and *Older than:* equals the percentage of animals that survives the age group. Tooth wear and development have not been used because of a limited number of age-determinable teeth. For wild boar, age determination was carried out according to Zeder et al. (2015), with the addition that some of their original detailed categories were combined into larger categories for a more comprehensive illustration due to the limited sample. For roe deer, epiphyseal fusion was analyzed according to Tome and Vinge (2003). Red deer epiphyseal fusion was analyzed using three different sources, because of the lack of a comprehensive study. Bosold (1966) was used for phalanges and metapodials, Lyman (1991) for the humerus, femur, radius and tibia, and Heinrich (1991) for the remaining skeletal elements. Seal age determination was based on epiphyseal fusion and measurement comparisons with modern seals according to Storå (2001). Measurements were been taken according to Von Den Driesch (1976) and on seals according to Ericson and Storå (1999).

3. Results and discussions

3.1. The exploitation of animals

The emergence of sedentism is a heavily discussed subject and has been examined from many different angles. Scandinavia can in no way be considered an isolated area during the Early Mesolithic period, and evidence of outside influences and interaction is apparent in the archaeological material in the spread of lithic blade technologies from the east (Sørensen et al., 2013). The interaction between groups of people is of interest regarding the emergence of sedentism, particularly because ethnographic evidence suggests that once sedentism is adopted by one group of people, neighboring groups often follow the same sedentary lifestyle, because sedentary groups tend to evolve into larger societies that make territorial claims, effectively denying smaller, mobile populations access to key areas (Kelly, 2013:107). Therefore, the emergence of sedentism in one area by one particular group of people signifies that it could be found elsewhere, or that evidence of other sedentary societies should emerge soon after in other areas, between which human interaction can be perceived.

The bone material from Norje Sunnansund reflected the location of the settlement: the inhabitants had exploited the whole of the surrounding environment. This pattern is visible at most Mesolithic sites, but is even more apparent at Norje Sunnansund because more

Table 1
The criteria's (epiphyseal fusion data and size and texture interpretations) used to divide the elements into different age categories. In some cases it has not been possible to determine if the seal phalanges were from the hind- or foreleg, in these cases the younger age category has systematically been assigned. px = proximal, di = distal.

Red deer	
1 year	Radius px, Coxae acetabulum, Scapula, Juveniles based on texture and size
1–2.5 years	Phalanx 1 + 2, Tibia di, Humerus di
2.5–4 years	Femur, Radius di, Ulna di, Metapodia di, Humerus px, Tibia px
>4	Vertebrae
Wild boar	
0–1.5 years	Atlas, Axis, Coxae, Scapula, Radius px, Phalanx 2, Humerus di, Juveniles based on bone texture and size
1.5–3 years	Phalanx 1, Tibia di, Metapodia, Fibula di
3-4 years	Calcaneus, Femur px
>4–5 years	Radius di, Femur di, Tibia px, Ulna, Fibula px, Humerus px
Roe deer	
0.5 year	Scapula, Acetabulum, Humerus di, Radius px, Phalanx 1 px, Atlas, Juveniles based on bone texture and size
1-2 years	Vertebrae, Humerus px, Radius di, Ulna, Metapodia, Femur, Tibia, Phalanges 2 px, Calcaneus
Seal	
Yearling	Posterior Phalanx 1 + 2 di, Metapodia 1 di, Acetabulum, Scapula, Anterior Phalanx 3 px, Humerus px, Yearlings based on texture and size
Juvenile	Tibia + Fibula px, Femur px, Humerus di, Radius px, Sacrum, Calcaneus px, posterior Phalanx 3 px, Juvenile based on size
Young adult	Humerus px, Femur di, Ulna px, Crural px, Anterior Phalanx 1 + 2 px
Old adult	Metapodia 1 px, Metapodia I-V di, Ulna di, Radius di, Crural di, posterior Phalanx 1 + 2 px, Vertebrae

species have been found there than at any other southern Scandinavian Early or Middle Mesolithic site (Boethius, 2017b). The high species diversity made it important to condense the information relevant to foraging strategies and interpretative signals into manageable entities, which was done by considering five different categories: seal hunting, fishing, ungulate hunting, opportunistic hunting and rodent intrusions. By means of this division; the central question of this study addresses the evidence of a delayed-return economy in the Scandinavian Early Mesolithic period and how subsistence strategies can provide evidence of a sedentary lifestyle.

3.1.1. *Seal hunting*

3.1.1.1. Seal hunting results. Traditional seal hunting has the potential to provide large quantities of food in a relatively short period of time. Furthermore, seal hunting may not be carried out solely for dietary needs (Storå, 2001:4), they can also be hunted for fur and blubber, adding to the importance of the animal. This significance is often observed in archaeological contexts, as seal hunting locations can generate large quantities of seal bone that dominate the bone assemblage (Aaris-Sørensen, 1978; Lindqvist and Possnert, 1997; Storå, 2001). At Norje Sunnansund both ringed seals and grey seals were present, although predominantly grey seals (Fig. 2). As the grey seal is the larger of the two species it was probably the most important as a source of meat and blubber; although considering that the majority of the seal bones have not been determined to species level a higher seal identification rate might prove this assumption wrong.

The seals found at the site displayed a seemingly even age distribution; around 60% of the bones from each age category have fused epiphyses and around 40% have unfused (Fig. 3). However, in this seemingly even fusion stage lays a highly uneven hunting pattern. Because the percentage of fused epiphyses is fairly constant in all categories, what is actually means is that only yearlings and old adults have been selected for hunt, if juveniles and young adults had been hunted the kill-off pattern would show an increasing prevalence of unfused bones with increasing age group. Thereby, almost half of the hunted seals were yearlings and the other half were old adults; with no, or very limited, amounts of hunted seals from the juvenile or young adult age group represented in the material (Fig. 3, lower). Furthermore, the presence of newly born seals (Fig. 4) and fetal bones in the area surrounding the fermentation facility, from both grey and ringed seals, indicated that seals in-calf might have been specifically targeted (Boethius, 2016).

3.1.1.2. Seal hunting discussion. The finding of newly born seals and seal fetuses is interesting from an environmental perspective, as ringed seals give birth within the ice during late winter to early spring (Almkvist et al., 1980) and modern grey seals in the Baltic give birth on top of the ice during late winter to early spring (Jensen, 2004). Therefore, the age distribution shown in Fig. 3 indicates the hunting of seal mothers and their young pups, which would have been found together on the ice, whereas the location of females that had not given birth and males would have been much less predictable and would probably be out of reach further out to sea. This means that seal hunting was primarily taking place on the ice during late winter to early spring. Seal hunting on the ice is not an uncommon interpretation; it is often assumed to have been carried out by people associated with the Middle Neolithic pitted ware culture on Gotland (Storå, 2001:31, 46), as well as being known from ethnographic accounts of circumpolar societies (Murdoch, 1892). The finding of a very young ringed seal (Fig. 4, left) and a ringed seal fetus is, however, an important environmental indicator, because they need ice thick enough to carry a snow shelter, which the mothers build within the ice (Härkönen, 2011). During the

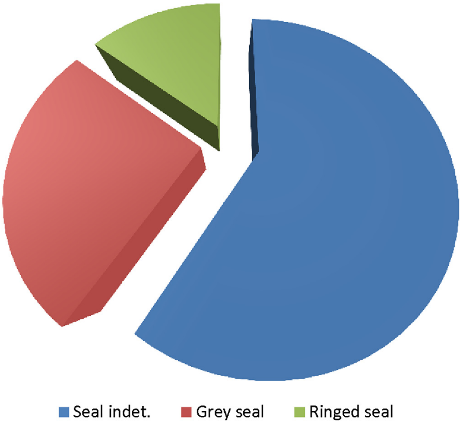

Fig. 2. Relative abundance of seal species based on NISP. N: grey seal (*Halichoerus grypus*) = 77, ringed seal (*Pusa hispida*) = 42, indeterminable (indet.) seal (Phocidae) = 172.

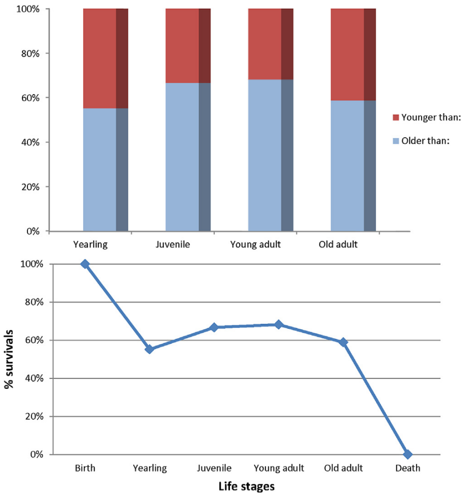

Fig. 3. Upper: Age distribution based on epiphyseal fusion and osteometrics on bones from grey seal, ringed seal and indeterminable seal species. Lower: Seal kill-off pattern derived from upper figure. Survivorship equals frequency of fused epiphysis in each age category, which in turn represents animals killed at an older age. Based on NISP in each category. n: *Yearling = 28, Juvenile = 12, Young adult = 22, Old adult = 17.*

boreal period, there was a continuous increase in temperature and the climate is considered to have been somewhat warmer than today (Antonsson, 2006), with the winters being about 1.5 °C colder in north-eastern Europe (Davis et al., 2003). The location of Norje Sunnansund suggests that it should have been impossible for ringed seals to breed in this area as the ice sheet would have been too thin. The most southern breeding area for ringed seal populations today is in the Gulf of Riga (Latvia), where the winter temperature is on average about 3.5 °C colder than in Blekinge, which means that if it was not cold enough the seals would have travelled further north and would not be available to hunt during the winter. An explanation for the presence of very young and fetal ringed seals in the Norje Sunnansund bone assemblage possibly lies with a known cold event. Around 9200 cal. BP, large volumes of freshwater were released into the Atlantic Ocean (Fleitmann et al., 2008), temporarily lowering the effect of the Atlantic thermohaline circulation, leading to a colder climate in the Northern Hemisphere. The effect of this event lasted no more than 150 years (Fleitmann et al., 2008; Rasmussen et al., 2007) but coincides with the older phase of the Norje Sunnansund settlement.

The age distribution pattern (indicating the hunting of mothers and their cubs), the osteometrics (indicating newly born seals and seal yearlings) and the presence of seal fetuses are indications of an unsustainable hunting practice that could not have been carried out for very long without depleting the local seal population. However, if viewed from the perspective of a short but intense cold spell, this type of hunting practice makes more sense, as it indicates a rapid adaptation to new climatic conditions. Given the relatively limited numbers of seal bones, compared with bones from fish and terrestrial mammals, it is possible that the hunting of seals at Norje Sunnansund was first and foremost carried out in order to supply fat and skins and that the toll extracted on the seals would not have been on a scale large enough to seriously harm the seal population.

3.1.2. Fishing

3.1.2.1. Fishing results. Fish bones were abundant at the site: up to 200,000 were found whereof around 13% have been analyzed, which has resulted in 16,180 identified and 4418 unidentified fish bones. The fish represented were all freshwater species, presumably because the adjacent lake, stream and Baltic basin were all freshwater at the time. Estimations based on the bone material analyzed from the oldest phase indicated that at least 48 tons of fish were caught (Boethius, 2017b). Less than 10% of the original site has been excavated so, taking the entire settlement into account, even larger quantities of fish were probably caught (Boethius, 2017b). The fish were dominated by cyprinids, mainly roach, which amounted to 75% of the total NISP, followed by perch, pike, eel and burbot, in declining order of presence (Fig. 5).

In addition to the large number of fish bones found at the site, a facility for fermenting fish was discovered. The fish fermentation facility (Fig. 6) consisted of an oblong pit filled with fish bones, surrounded by post holes, for roof bearing poles, and smaller stake holes, which once held stakes used for tightening wild boar and seal skins containing the fermenting fish (Boethius, 2016). This has

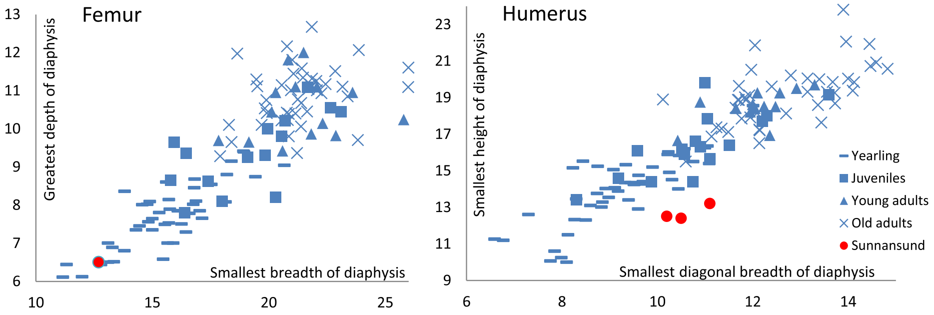

Fig. 4. Size of ringed seal femur and humeri from Norje Sunnansund compared with modern ringed seals. Measurements of modern seals and age group division courtesy of J. Storå (Storå, 2001:paper II). Measurements in millimeters according to Ericson and Storå (1999). Two of the humeri fragments and the femoral fragment from Norje Sunnansund were assigned to the *younger than* yearling category and one of the humeral fragments to the *younger than* juvenile category in Fig. 3 above.

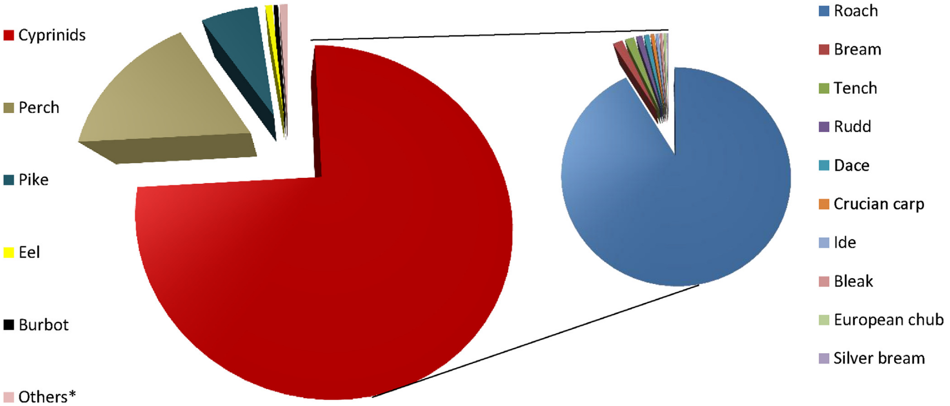

Fig. 5. Relative abundance of fish species based on NISP. Left: cyprinids (cyprinidae) = 11,978, perch (*Perca fluviatilis*) = 2728, pike (*Esox lucius*) = 1098, eel (*Anguilla anguilla*) = 138, burbot (*Lota lota*) = 83, others = 155. *: pike-perch (*Sander lucioperca*) = 53, ruffe (*Gymnocephalus cernua*) = 35, whitefish (*Coregous* sp.) = 32, smelt (*Osmerus eperlanus*) = 10, salmon/trout (*Salmo salar*/*trutta*) = 9, percinids (percidae indet.) = 13, Arctic char (*Salvelinus alpinus*) = 3. Right: Cyprinid bones determined to species. Roach (*Rutilus rutilus*) = 1016, Bream (*Abramis brama*) = 20, Tench (*Tinca tinca*) = 19, Rudd (*Scardinius erythrophthalmus*) = 13, Dace (*Leuciscus leuciscus*) = 11, Crucian carp (*Carassius carassius*) = 8, Ide (*Leuciscus idus*) = 7, Bleak (*Alburnus alburnus*) = 6, European chub (*Squalius cephalus*) = 6, Silver bream (*Blicca bjoerkna*) = 3.

been linked directly with the conservation and storage of food products and is therefore associated with a delayed-return subsistence practice.

3.1.2.2. Fishing discussion. The amount of fish bone found at Norje Sunnansund is itself a good indicator of a sedentary lifestyle (Boethius, 2017b). These volumes of fish would have been enough to support a large number of people during many years of site occupation. Large volumes of caught fish are most probably associated with a sedentary society applying mass-harvesting technologies, such as stationary fish traps and nets, to catch the fish during predictable events when the fish are especially abundant in the area (Kelly, 2013:127); at Norje Sunnansund this would have been during the autumn, when roach aggregate to fake-spawn, and during the spring, when roach do spawn (Curry-Lindahl, 1969). Furthermore, mass catches imply the creation of storage facilities and the preservation of fish. The fermentation facility found at the site provides evidence of this, and offers an insight into complex methods of food storage (Boethius, 2016). The preservation and storage of fish are good indications of a delayed-return economy, where investment in both the method of catching the fish and the time needed for the fish to ferment properly provides edible food months after the catch was landed. Large amounts of caught fish would have generated enough food to sustain a large number of people throughout most of the year, and therefore meet the subsistence requirements of a sedentary settlement. In ethnographic reports of foraging societies, an increase in reliance on aquatic resources is generally combined with a lower rate of movement (Marlowe, 2005:Fig. 6), and a high reliance on aquatic resources is, in itself, an argument for a higher degree of sedentism. Furthermore, sedentary foraging societies are generally much larger than mobile terrestrial hunter societies, especially if aggregated during the winter (Kelly, 2013:167,172). In addition, in areas with abundant resources, demographic modelling suggests rapid human population growth (Kelly, 2013:185) that, if considered in a sedentary aquatic-dependent community, implies a large number of residents and subsequent expansion into neighboring areas as the original area becomes packed (over-crowded). In Binford's opinion a '*heavy use of aquatic resources was itself a density-dependent response*' (Binford, 2001:385,423).

3.1.3. Ungulate hunting

3.1.3.1. Ungulate hunting results. The ungulates at Norje Sunnansund were dominated by red deer and wild boar, closely followed by roe deer, which together made up about 95% of the ungulate assemblage (Fig. 7). Aurochs and elk were represented by just a small number of identified fragments. Even though they would only have occurred in small numbers in the landscape, they appeared to have been of lesser dietary importance compared with the smaller ungulates (Fig. 7). The low abundance of both aurochs and elk is interesting, as they are generally more common at Early Mesolithic sites (Magnell, in Print). However, most contemporaneous sites, except Huseby Klev and Balltorp on the Swedish west coast which also have low numbers of elk and aurochs (Boethius, 2017a; Jonsson, 1996, 2014), are from inland locations. Thereby, elk and aurochs abundance could indicate a pronounced divergence between inland and coastal sites.

The age distribution of the smaller ungulates suggested a selective hunting approach. There was a low out-take of juveniles for both roe deer and red deer, and a high kill-off rate between 2.5 and 4 years old for red deer (Fig. 8). A different kill-off pattern was seen with the wild boar, which showed a more equal hunting pressure across all ages; indicated by decreasing prevalence of wild boars with fused epiphyses with increasing age.

3.1.3.1. Ungulate hunting discussion. The dissimilarities in the kill-off patterns between the cervids, especially red deer, and wild boar, have implications for the interpretation of the terrestrial hunting activities. The age distribution of cervids indicates a small out-take of individuals younger than 2 years, suggesting a selective hunting pattern. The red deer show a high kill rate between 2.5 and 4 years old, when individuals would have reached full body size and provided an optimum amount of meat; it would also have been before the males reached reproductive age, which occurs later than

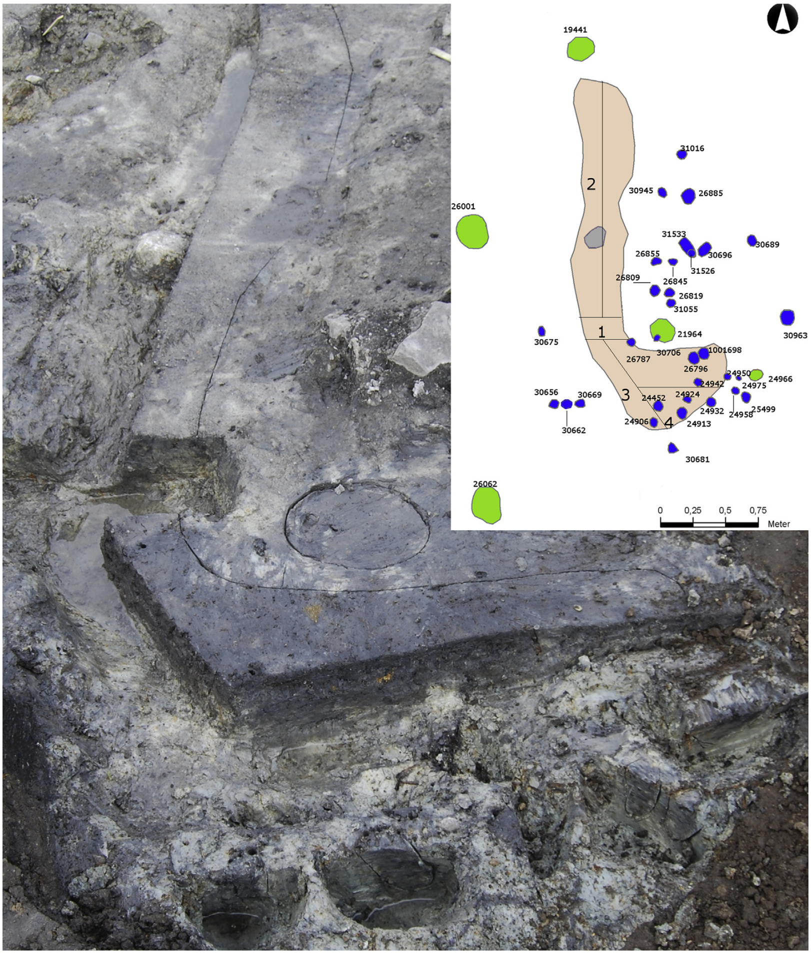

Fig. 6. The fish fermentation facility when half of the feature had been removed (main picture) and a plan of the feature (upper right) including the gutter with its surrounding post- and stakeholes. Picture and further explanation in Boethius (2016). Photo: SHMM.

sexual maturity in a well-functioning red deer hierarchy[2] (Clutton-Brock et al., 1979; Clutton-Brock and Guinness, 1982). This is a pattern known from many Mesolithic settlements in southern Scandinavia (Bay-Petersen, 1978; Boethius, 2017a; Magnell, 2006). However, the wild boars were hunted from younger ages, which imply that not all species were hunted once they had reached full body size. More intricate hunting strategies appear to have caused the observed kill-off patterns.

Wild boars are highly fecund, giving birth to between four and six, sometimes more, piglets each breeding period, and they can breed successfully twice a year if circumstances are favorable (Briedermann, 1990)[3]. However, wild boars also have a high natural mortality rate and studies have shown that about 48% of wild boars die within the first year of life (Jezierski, 1977). It is suggested, therefore, that the high mortality among wild boar piglets is of low significance to the future of the population (Jezierski, 1977), so a

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[2] The effective reproduction age of red deer does not normally occur until 5 years old, as males compete and earn their place to hold harems and reproduce and young stags are unable to control and protect hinds.

[3] Around 85% of modern Swedish wild boar piglets are born between February—May and there is no reason to suspect that the same does not apply to Mesolithic Scandinavia (Magnell, 2006).

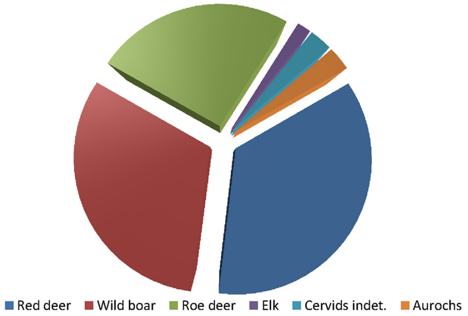

Fig. 7. Relative abundance of ungulate species. NISP: red deer (*Cervus elaphus*) = 373, roe deer (*Capreolus capreolus*) = 271, elk (*Alces alces*) = 19, cervids indet. (Cervidae) = 31, aurochs (*Bos primigenius*) = 32, wild boar (*Sus scrofa*) = 331.

safe higher out-take is possible. Both roe deer and especially red deer have a different reproduction strategy compared with wild boar. In areas with limited predation, studies have shown that red deer hinds give birth to an average of 0.7–0.78 calves a year, resulting in an average of 4.4–6.8 calves that reach 1 year of age during a hind's lifetime (Clutton-Brock et al., 1986). A high out-take of young red deer will therefore soon deplete a local population. This becomes even more evident when other predators are taken into account, which typically prey on the young (Okarma, 1995). Roe deer can be subjected to a somewhat higher hunting pressure as they reach reproductive age earlier than red deer and often gives birth to two fawns a year (Vincent et al., 1995).

The different kill-off pattern seen between the two cervid species and wild boar indicate different hunting strategies for different species. These hunting strategies could be considered conservative, working to maximize the gain from each killed animal from species with a lower reproduction rate. Environmental conservation practices are known from ethnographic sources, for example Alaskan Iñupiats commonly open their fishing weirs, releasing half of their catch, to ensure a future fish population (Burch, 2007), and riverine communities in north-western American consciously avoid blocking entire rivers as they know it will have disastrous effects (Erlandson and Rick, 2008). The Huna Tlingit in Alaska are reported to practice conservative glaucous-winged gull (*Larus glaucescens*) egg harvest by only selecting eggs from nests containing one or two eggs, as this will trigger the female to continue laying eggs until there are three eggs in the nest (Hunn et al., 2003). Other accounts of managing the environment have been reported from North America, such as the burning of brush vegetation to increase harvest and produce fresh saplings for grazing ungulates, and pruning

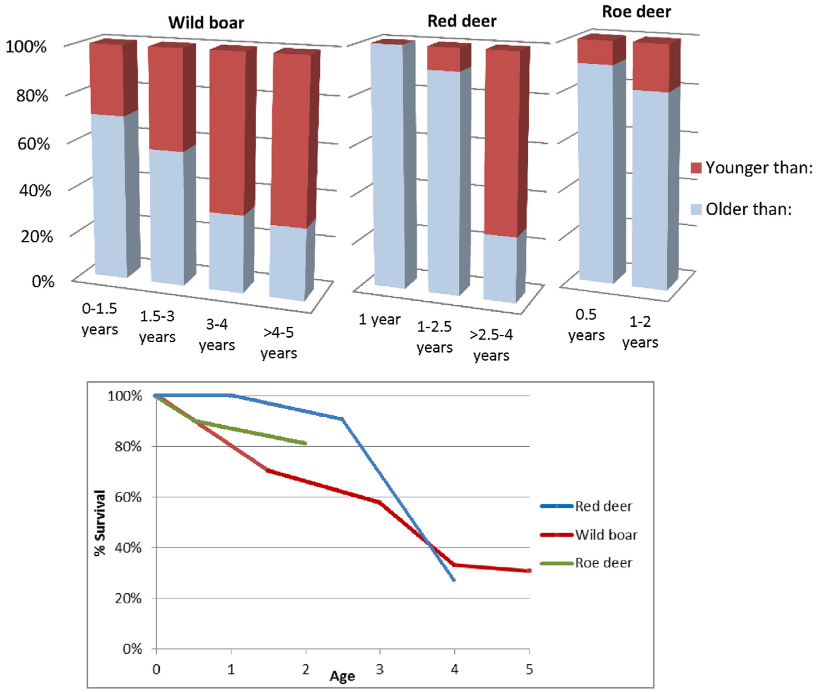

Fig. 8. Upper: Kill-off patterns based on the epiphyseal fusion ages of different elements of the post-cranial skeleton for wild boar, red deer and roe deer at Norje Sunnansund. Survivorship equals frequency of fused epiphysis in each age category, which in turn represents animals killed at an older age. Based on NISP in each age category for: Wild boar: 0–1.5 years n = 17, 1.5–3 years n = 26, 3–4 years n = 6, >4–5 years n = 26. Red deer: 1 year n = 3, 1–2.5 years n = 22, >2.5–4 years n = 11. Roe deer: 0.5 year n = 21, 1.5–2 years n = 32.

of trees and plants (Anderson, 2005). However, as Kelly so eloquently puts it *'The question is not whether foragers conserve their resources. Some do and some do not. The question is: under what conditions would we expect to see behaviors that intentionally manage and conserve resources, as well as cultural concepts that encourage such behaviors'* (Kelly, 2013:112).

Arguments for selective red deer hunting strategies among Mesolithic foragers were made at the beginning of the 1970s, with claims of a large majority of males in the faunal assemblage from Star Carr in Britain (Jarman, 1972). However, when calculating the sex ratio the numbers included antler fragments and, as only males have antlers, which can also be collected when they are shed, Jarman (1972)'s arguments were seriously biased. Furthermore, hinds can also be culled in order to maximize the body and antler size of living stags (Clutton-Brock and Albon, 1989), which, if applied, imply the collection of shed antlers. The collection of shed antlers is commonly observed at both Norje Sunnansund, were 80% of the red deer antlers[4] ($n = 5$) originated from a shed antler, and in other Mesolithic contexts (Legge and Rowley-Conwy, 1988). Because of the lack of complete bones for analyzing osteometric sex ratios and the lack of sex-determinable pelves, age profiling may be the only realistic means of investigating hunting strategies. Although rare in Mesolithic contexts, selective red deer hunting has been suggested in the oldest phase at coastal Tågerup, southwestern Sweden, dated to the Middle Mesolithic period. At this site, young red deer as well as red deer in their prime are absent from the bone assemblage, similar to the pattern seen at Norje Sunnansund, whereas both roe deer and wild boar appeared to be non-selectively hunted, displaying animals from all age groups (Eriksson and Magnell, 2001). This pattern is also observable at the Early Mesolithic Swedish west-coast site of Huseby Klev, although a low number of age-assessable fragments complicates the interpretation (Boethius, 2017a). Thereby, Kelly's question of '*under what conditions*' a selective hunt for different ungulate age groups is implemented can perhaps be answered if it can be said that this strategy is common on settlements close to large aquatic resources.

Because of the benefits of these particular types of hunting strategy, it could be argued that they are the unintentional and epiphenomenal by-product of optimal foraging decisions (Alvard, 1993; Aswani, 1998) or that they emerged as a response to an earlier depletion of required resources (Berkes and Turner, 2006). The actions taken to secure a sustainable caribou harvest following the over-exploitation of caribou by Chisasibi Cree native Canadians indicate that restrictive hunts and managing strategies can emerge as a response to human-induced local extirpation (Berkes and Turner, 2006:483). Given how common both aurochs and elk are in the archaeological material from contemporaneous inland sites, it could be argued that there is no apparent reason for them to be absent at coastal sites unless human over-exploitation had depleted the coastal zones of the largest animals with the slowest reproduction rates. If this was the case, the over-exploitation must have happened prior to the human occupation of Norje Sunnansund, but, as no prior settlements have been found, because they would be located under the current water level as a result of the transgression following the melting of the ice, this interpretation is speculative. However, the available evidence suggests a lack of larger ungulates in coastal areas that, in combination with selective red deer hunting strategies, implies prior over-exploitation of aurochs and elk in coastal zones, followed by more restrictive hunting strategies. A local extirpation or low numbers of larger ungulates in coastal areas might also imply larger human populations than previously realized. Therefore, ungulate hunting strategies and kill-off patterns are something that should be taken into account when discussing human impact on the environment, even as far back as the Early Mesolithic.

Conservative hunting strategies, independent of the reason for their implementation, would only be possible in sedentary, aggregated societies not yet experiencing overcrowding, which would be the case as long as the areas occupied by neighboring groups of people did not intrude on the territory of the original group. If at some point an area became too crowded, people would start to move and permanently settle in areas within the group's territory, with the abandonment of restrictive hunting strategies. This would be done for pragmatic reasons, as it could not be assumed that another group of people would practice similar hunting strategies. The potential of another group to extract too large a toll on prime animals, females and juveniles would force the original group to do likewise, otherwise they would risk being without any of the resource. Therefore, conservative hunting strategies applied to cervid species should only be observable in sedentary societies not yet experiencing competition. This phenomenon is possibly observable in the Late Mesolithic Ertebølle phase of Tågerup (Eriksson and Magnell, 2001), where such a change in red deer kill-off pattern is hinted at, even though the interpretation is complicated by only small numbers of age-determinable fragments in the Ertebølle phase.

3.1.4. *Opportunistic hunting*

There is no compelling evidence of a delayed-return economy in animals hunted for fur (here referred to as fur-game) or in bird-hunting strategies. The abundance of the different species represented, in combination with the limited number of identified specimens from each species, gave the impression of more opportunistic hunting. However, the fur-game and bird species present did provide some interesting topics for discussion concerning selective hunting strategies and possible seasonality indicators.

3.1.4.1. *Animals hunted for fur*

3.1.4.1.1. Animals hunted for fur results. There was no evidence of juvenile fur-game, a total of 72 fur-game bone elements have fused epiphyses and not one single bone from any of the fur-game show an unfused epiphysis, even though different species with varied reproductive strategies were represented. Most of the fur animal assemblage from Norje Sunnansund comprised small species, the most common being squirrels, pine martens and otters; however, larger species such as badger, fox, bear, beaver and wolf are also frequently occurring (Fig. 9).

If studying fur-game elemental frequencies it is possible to distinguish a size specific pattern (Fig. 10). Small fur-game, in general, lack elements from the body core, while the larger species have a more evenly represented elemental distribution. However, as the body core elements are smaller and less dense than the other parts of the body this might be a taphonomic issue, as the different parts of the body otherwise, in general, are represented. Thereby, it appears as if complete bodies often have been transported to the settlement, albeit with some exceptions. Limb bone fragments from pine marten and red fox are relatively rare, indicating that these species might have been skinned at the trapping location without the meat having been brought back to the site. Similarly, beavers are largely represented by cranial fragments (mainly teeth), which might indicate that their skulls have been collected to acquire the teeth to use as tools, something which has been observed at other Mesolithic sites (Hatting, 1969).

3.1.4.1.2. Animals hunted for fur discussion. The fur-game age pattern is interesting and can be interpreted both as reflecting the season of catch and as the result of selective hunting strategies,

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[4] I.e. of the antlers which were assignable to either a shed antler or a killed animal (e.g. were antler is still attached to a skull); on most of the antler fragments from the site this cannot be determined.

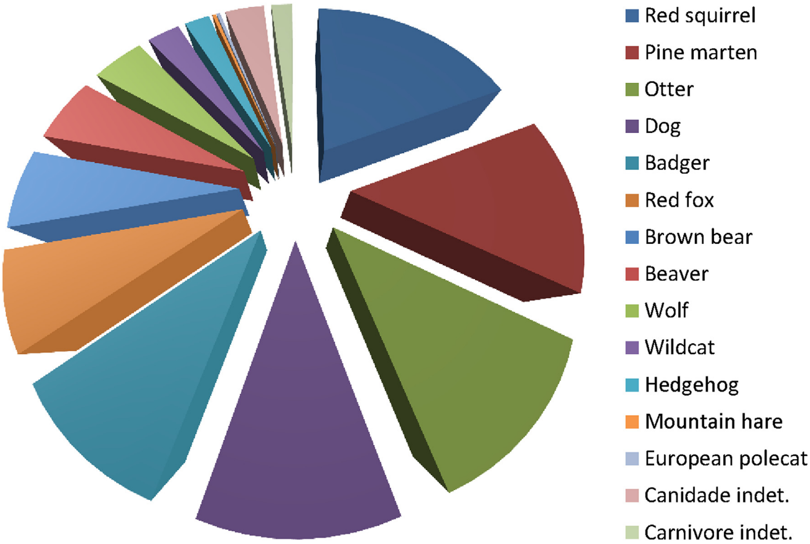


Fig. 9. Relative abundance of animals hunted for fur species. *NISP* = 300: red squirrel (*Sciurus vulgaris*) = 57, pine marten (*Martes martes*) = 42, otter (*Lutra lutra*) = 36, dog (*Canis familiaris*) = 32, badger (*Meles meles*) = 29, red fox (*Vulpes vulpes*) = 22, brown bear (*Ursus arctos*) = 19, beaver (*Castor fiber*) = 17, wolf (*Canis lupus*) = 14, wildcat (*Felis silvestris*) = 9, hedgehog (*Erinaceus europaeus*) = 7, mountain hare (*Lepus timidus*) = 1, European polecat (*Mustela putorius*) = 1, canidade indet. = 11, carnivora indet. = 6.

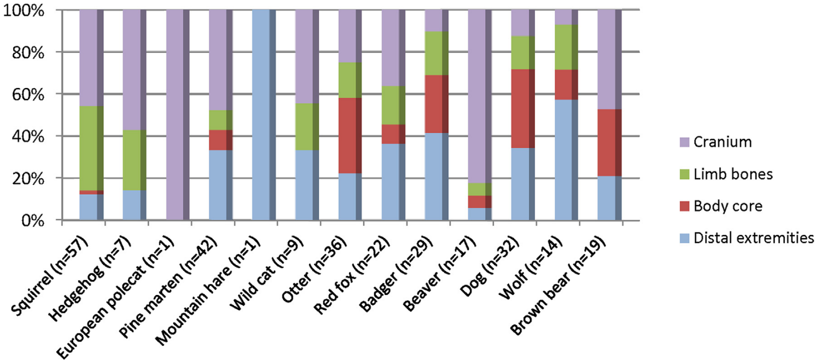


Fig. 10. Elemental distribution of fur animal species ordered according to size and based on NISP.

depending on the individual species. The presence of fur-game species in bone assemblages has commonly been argued to indicate a winter occupation (Enghoff, 2011). Fur-games can be hunted all year round, but winter pelts from most fur species are more desirable than the summer pelts (Andersson, 2006) because their insulating properties are optimal (Hart, 1956). A higher frequency of fur-game hunting can therefore be expected during the winter season, if there are indications of a sedentary lifestyle with occupation during most of the year.

Small fur-game were probably hunted using passive, unselective methods, such as wires and traps, because it is the easiest way to catch small animals (Ekman, 1910); however, it is also possible to hunt small fur game using active methods. The most frequently occurring fur-game are squirrel and pine marten, which are fast-growing species who are completely full-grown within a year of birth (Degn, 1973; Trolle-Lassen, 1986). Thereby, the presence of only fully grown small fur-game species suggest that they were hunted towards the end of winter, by which time the cubs born last spring would have matured and their epiphyses fused. It could be argued that juveniles have a different moving pattern than adults and stay secluded in the burrow or nest while the adult animals forage for food. However, while this is true during the first months after birth it changes gradually and well before small fur-game, e.g. squirrels and pine martens, are fully grown they move and forage for food alike their parents. Furthermore, it can be argued that bones from juveniles preserve badly, and that the pattern is the result of taphonomic loss. However, this was counter-indicated by the large number of fish bones recovered from the site, which are normally less well preserved than bones from young mammals. Thereby, the hunt of small fur-game appears to have taken place during the winter when their bones had fused epiphyses, indicating that they were fully grown and close to one year old. This seasonality indicator is further enhanced if comparing epiphyseal fusion data from sites, such as late Mesolithic Tybrind Vig in Denmark, where large amounts of pine martens have been hunted. Here epiphyseal data suggest that pine martens were mainly hunted in late autumn, with two thirds of the bone elements from the assemblage still unfused (Trolle-Lassen, 1986).

Similar to the small fur-game; only fully grown large fur-game is present in the material. However, animals such as badger, fox, bear, beaver and wolf ages slower than the above mentioned small fur-game and as such their fully grown bodies cannot be an indication of the hunt occurring during the winter and the pattern seen in the epiphyseal fusion stage of large fur-game must be understood differently. Considering the presence of exclusively fully grown fur-game in combination with the elemental distribution it appears as if adult large fur-game species could have been selectively targeted, possibly for their larger pelts. This implies a similar hunting strategy compared to cervid species if they can be said to have been selectively hunted around the time when they reached full body size (see paragraph 3.1.3.1.). Furthermore, it could also be suggested that different fur-game species were differently utilized, some having been brought back to the settlement more or less complete, presumably because their meat or other products were needed, while other species were skinned at the kill site and only the skins, with attached skull and feet, have been brought back to the settlement.

The smaller fur-game species could also have been selectively targeted; however, given that passive hunting methods are often used while hunting small game and because even if active methods were used it would have been an effort to single out only fully adult animals, typically as species such as pine marten receive their adult winter fur at the onset of the first winter (Trolle-Lassen, 1986) and thus would appear similar, at a distance, to older adults. Thereby, it is more likely that the observed pattern is an indication that small fur-game were primarily hunted during the end of the winter season.

3.1.4.2. Bird hunting

3.1.4.2.1. Bird hunting results. The birds from Norje Sunnansund were diverse and represented by species from many different biomes, such as small water courses as well as large lakes, the sea and forests. Bones from migrating birds have traditionally been used to interpret both seasonal occupation and to a lesser extent climate (Bratlund, 1991; Enghoff, 2011:269). In the case of Norje Sunnansund, the evidence provided by the bird species indicated bird hunting at least during the migration periods (Fig. 11). However, they were not necessarily hunted only during migrations. Birds have complex movement patterns, and birds moving to higher latitudes for the summer will be available during the spring and autumn. There can also be variation in the timing of migration within a bird species, with different birds having an individually optimized migration schedule (Battley, 2006; Vardanis et al., 2011).

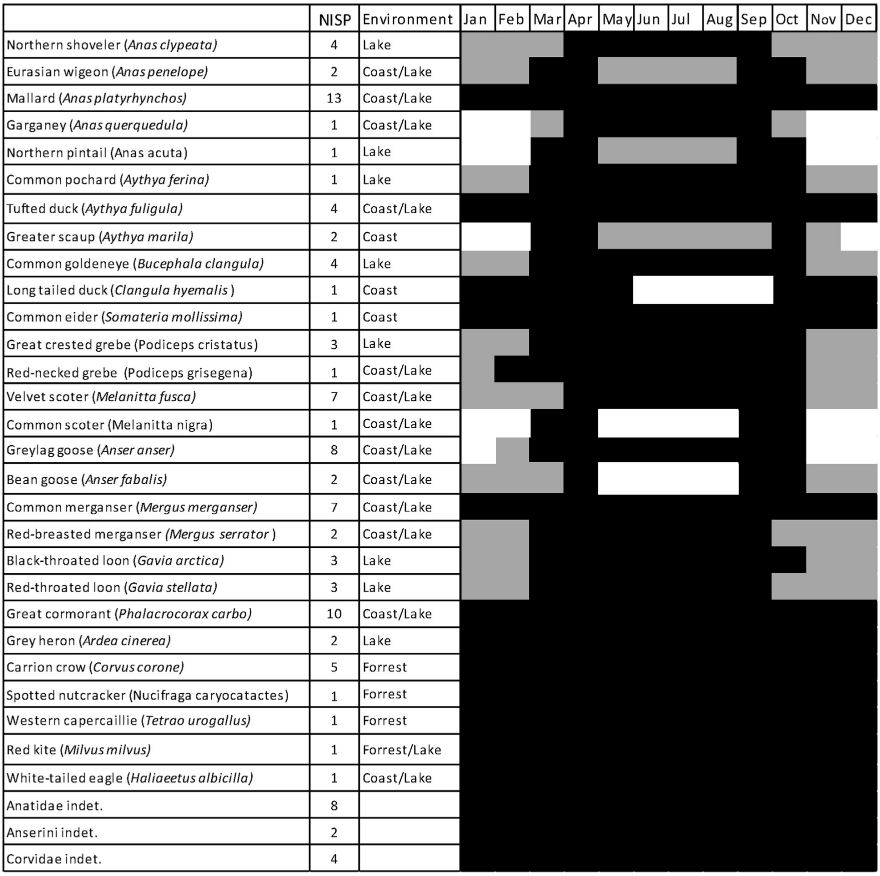
3.1.4.2.2. Bird hunting discussion. The presence of different seasonal birds throughout the year was similar to the pattern seen in Danish Ertebølle settlements and, as birds from all seasons were present in the assemblage, it was difficult to demonstrate seasonality and site abandonment based solely on bird bones (Rowley-Conwy, 1983). The many bird species found in the bone material represent both migrating and native birds, where migrating birds from all seasons were present. Even though birds are, in general, easier to catch during the winter, because of their flocking behavior, and consequently fowling is often a cold season activity (Serjeantson, 2009), some of the birds present could also have been hunted during the summer. Therefore it is difficult to observe seasonality or site abandonment based on the bird bones, as the species could have been hunted throughout the year. Thus bird-hunting may be considered an all year around activity, albeit one that was mainly done when the opportunity came and not an actively sought activity, indicated by the large number of species being represented by a limit amount of bird bone fragments.

3.1.5. Rodent intrusions

3.1.5.1. Rodent results. At Norje Sunnansund, rodents (small rodents from the Muridae and Cricetidae families) made up about 13% ($n = 253$) of the total mammal NISP. However, it was difficult to compare these numbers with other Scandinavian sites. At Norje Sunnansund all excavated soil was water sieved, using a 4 mm mesh sized sieve on 55% of the excavation and a 2.5 mm mesh on the remaining 45%, with mesh sizes small enough to recover rodent bones. However, previous excavations on contemporaneous sites have rarely used water sieving over the entire site and therefore small rodent bones were recovered more randomly, preventing an unbiased rodent frequency comparison. For the same reason, it was difficult to make a spatial comparison of rodent presence across Scandinavian archaeological settlements. Furthermore, as many rodents are burrowing species and can be intrusive, it is difficult to know the origin of rodent bones found in archaeological contexts. However, at Norje Sunnansund spatial analysis was possible and, because the entire site was covered by a transgression around the time of abandonment, there were no later intrusions and the rodents found were contemporary with the occupation of the site (Fig. 12). When later intrusions can be ruled out, the spatial distribution of rodents can provide important information because rodents (at least the commonly considered commensal species) are often connected with the presence of built structures and food storage (O'Connor, 2013:50; Tangri and Wyncoll, 1989:91).

3.1.5.2. Rodent discussion. The potential of identifying sedentary societies from an increase in the relative abundance of commensal animals has long been argued in archaeological contexts from the Middle East (Hesse, 1979; Tchernov, 1984). However, on its own the presence of typical commensal animal species does not indicate sedentism, as these species have existed at human settlement sites before sedentary societies emerged (Tangri and Wyncoll, 1989), and an increase in abundance can correspond with an increase in settlement size (O'Connor, 2013:43).

Evidence from Late Pleistocene Natufian settlements in the Levant indicates large quantities of house mouse (*Mus musculus*), black rat (*Rattus rattus*) and house sparrow (*Passer domesticus)* bones in the osteological assemblages (Bar-Yosef and Belfer-Cohen, 1989:473). Although there is not always a consensus of how to interpret typically commensal animals in pre-Neolithic contexts (Tangri and Wyncoll, 1989; Tchernov, 1991; Wyncoll and Tangri, 1991), it is generally agreed that omnivorous commensal animals thrive in the refuse of human societies. The best methods for quantifying the presence of commensal species, in order to understand the level of sedentism, are also heavily debated, and range from counting the relative abundance of typical commensal murinids in owl pellets (Tchernov, 1984) to examining their relative abundance in wells (Cucchi et al., 2002). Even though a general approach is biased by taphonomic factors such as inter-specific site variation in excavation methodology and preservation, a quantitative approach can provide information if sites with similar excavation methods and preservation are compared.



	NISP	Environment	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Northern shoveler (*Anas clypeata)*	4	Lake	▨	▨	▨	■	■	■	■	■	■	▨	▨	▨
Eurasian wigeon (*Anas penelope)*	2	Coast/Lake	▨	▨	■	■	▨	▨	▨	▨	■	■	▨	▨
Mallard (*Anas platyrhynchos)*	13	Coast/Lake	■	■	■	■	■	■	■	■	■	■	■	■
Garganey (*Anas querquedula)*	1	Coast/Lake	□	□	▨	■	■	■	■	■	■	▨	□	□
Northern pintail (Anas acuta)	1	Lake	□	□	■	■	▨	▨	▨	▨	■	■	□	□
Common pochard (*Aythya ferina)*	1	Lake	▨	▨	■	■	■	■	■	■	■	■	▨	▨
Tufted duck (*Aythya fuligula)*	4	Coast/Lake	■	■	■	■	■	■	■	■	■	■	■	■
Greater scaup (*Aythya marila)*	2	Coast	□	□	■	■	▨	▨	▨	▨	▨	■	▨	□
Common goldeneye (*Bucephala clangula)*	4	Lake	▨	▨	■	■	■	■	■	■	■	■	▨	▨
Long tailed duck (*Clangula hyemalis*)	1	Coast	■	■	■	■	■	□	□	□	□	■	■	■
Common eider (*Somateria mollissima)*	1	Coast	■	■	■	■	■	■	■	■	■	■	■	■
Great crested grebe (Podiceps cristatus)	3	Lake	▨	▨	■	■	■	■	■	■	■	■	▨	▨
Red-necked grebe (Podiceps grisegena)	1	Coast/Lake	▨	■	■	■	■	■	■	■	■	■	▨	▨
Velvet scoter (*Melanitta fusca)*	7	Coast/Lake	▨	▨	▨	■	■	■	■	■	■	■	▨	▨
Common scoter (Melanitta nigra)	1	Coast/Lake	□	□	■	■	□	□	□	□	■	■	□	□
Greylag goose (*Anser anser)*	8	Coast/Lake	□	▨	■	■	■	■	■	■	■	■	□	□
Bean goose (*Anser fabalis)*	2	Coast/Lake	▨	▨	▨	■	□	□	□	□	■	■	▨	▨
Common merganser (*Mergus merganser)*	7	Coast/Lake	■	■	■	■	■	■	■	■	■	■	■	■
Red-breasted merganser *(Mergus serrator*)	2	Coast/Lake	▨	▨	■	■	■	■	■	■	■	▨	▨	▨
Black-throated loon (*Gavia arctica)*	3	Lake	▨	▨	■	■	■	■	■	■	■	■	▨	▨
Red-throated loon (*Gavia stellata)*	3	Lake	▨	▨	■	■	■	■	■	■	■	▨	▨	▨
Great cormorant (*Phalacrocorax carbo)*	10	Coast/Lake	■	■	■	■	■	■	■	■	■	■	■	■
Grey heron (*Ardea cinerea)*	2	Lake	■	■	■	■	■	■	■	■	■	■	■	■
Carrion crow (*Corvus corone)*	5	Forrest	■	■	■	■	■	■	■	■	■	■	■	■
Spotted nutcracker (Nucifraga caryocatactes)	1	Forrest	■	■	■	■	■	■	■	■	■	■	■	■
Western capercaillie (*Tetrao urogallus)*	1	Forrest	■	■	■	■	■	■	■	■	■	■	■	■
Red kite (*Milvus milvus)*	1	Forrest/Lake	■	■	■	■	■	■	■	■	■	■	■	■
White-tailed eagle (*Haliaeetus albicilla)*	1	Coast/Lake	■	■	■	■	■	■	■	■	■	■	■	■
Anatidae indet.	8		■	■	■	■	■	■	■	■	■	■	■	■
Anserini indet.	2		■	■	■	■	■	■	■	■	■	■	■	■
Corvidae indet.	4		■	■	■	■	■	■	■	■	■	■	■	■

Fig. 11. Hunting seasons for the different bird species represented in the oldest layer, given the assumption that bird migration patterns have not changed significantly during the last 9000 years. Black indicates presence, grey possible presence and white absence. Based on data from Imby (1987) and Ekberg and Nilsson (1994, 1996).

On Norje Sunnansund it is apparent that most rodent bones were clustered in one specific area of the excavation (Fig. 12). This corresponds with the location of the fish fermentation feature. This is interesting, given the nature and common abundance of commensal rodent species in permanent structures and storage facilities, as noted above. However, determining which species are commensal is not straight forward, and can depend on location and environmental conditions, with different species living commensally at different human settlements (O'Connor, 2013:11). The most commonly considered commensal rodents today are probably rats and the house mouse. These murid species had not been introduced to Scandinavia 9000 years ago, but other rodents can behave in a similar manner and non-typical rodents can be considered commensal. Bearing in mind the discrepancy in which species can be considered commensal in different areas under differing circumstances (O'Connor, 2013:11), and the arguments regarding a larger commensal species diversity in the past (O'Connor, 2013:134), the implications of the concentrated presence of rodent bones centered on the fermentation pit at Norje Sunnansund, as shown in Fig. 12, are important; as it implies that native Scandinavian murine and cricetine species are comparable with the commensally recognized house mouse (*Mus musculus*) and rat species (*Rattus norvegicus/rattus*), especially if the latter species are not present at a certain location and if conditions are favorable.

The evidence from Norje Sunnansund strengthens the view that different species can become commensal, if the right conditions are met. At Norje Sunnansund, most of the identified rodent bone fragments come from water voles (*Arvicola amphibius*), yellow-necked mice (*Apodemus flavicollis*) and field voles (*Microtus agrestis*), which are generally herbivorous and not omnivorous species. However, water voles have been known to eat toads, for example there are accounts of numerous half-eaten toads in connection with water vole droppings and cut sedges (Oda Dijksterhuis, Canal & River Trust, personal communication, April 7, 2016), and fish

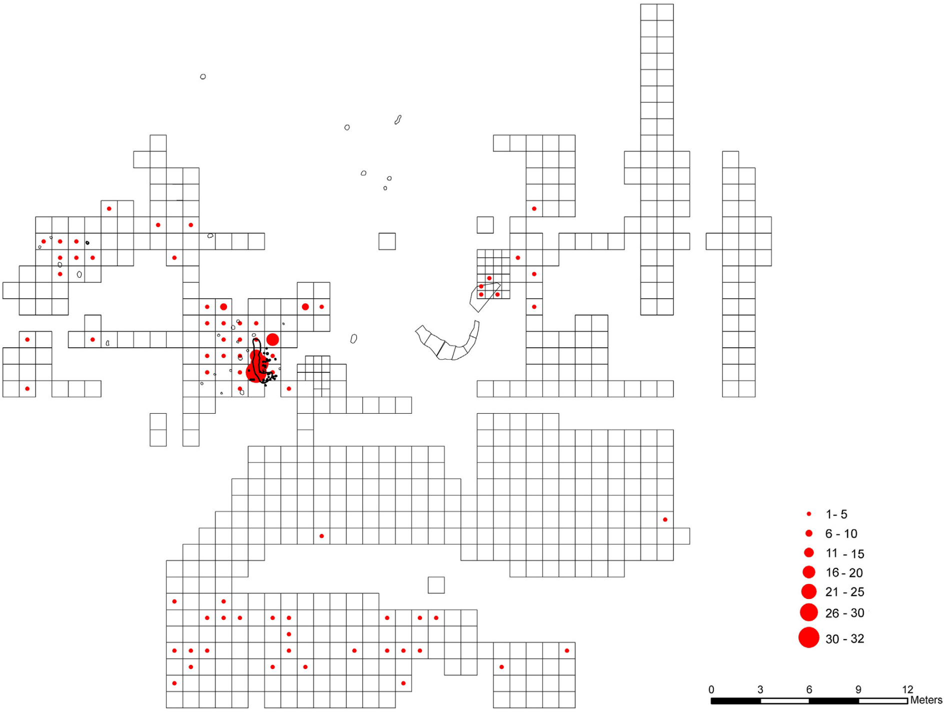


Fig. 12. The distribution and frequency of rodents at Norje Sunnansund based on NISP (red dots) within the excavation units and features from the site. NISP: water vole (*Arvicola amphibius*) = 63, yellow-necked mouse (*Apodemus flavicollis*) = 9, field vole (*Microtus agrestis*) = 9, rodent indet. (Muridae/Cricetidae) = 158. The rodent bones from the preliminary excavation not included in the figure. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

(Curry-Lindahl, 1988:270) under certain circumstances, suggesting a need to add protein to their diet. Yellow-necked mice are known to sometimes eat mammal cadavers (Curry-Lindahl, 1988:287). The presence of field voles around the fermentation pit is harder to explain because they are grass eaters that have never been observed to eat animals. However, field voles are commonly known to eat bark during the winter when fresh grass is sparse (Jensen, 2004:169), and interestingly the fermentation facility was covered with bark to aid the fermentation process (Boethius, 2016), which might, as well as the shelter offered by the construction, be the explanation for their presence. The evidence from Norje Sunnansund seems to suggest that some normally herbivorous cricetids and murinids can be omnivorous if specific criteria are met, such as easily available protein-rich food, for example the residue after a successful fermentation. Furthermore, it suggests that rodent species not commonly considered commensal can utilize a commensal living space, possibly more so when more typical commensal species are not present, which is known to modern pest-control agencies and ecologists as they are well aware of house intrusions by yellow-necked mice and backyard destruction by water voles (Anticimex, 2013; Jensen, 2004). Their increased rodent abundance in the vicinity of the fermentation facility suggests that the construction was a permanent installation, offering shelter and food for the rodents, the wall and roof structure providing them with a suitable habitat. Even though a permanent construction on a settlement should not be regarded as evidence of permanent occupation (Boyd, 2006:170), because the structure could be returned to over different time intervals, the increased abundance of rodents around this structure suggests a pattern similar to commensal animals in early sedentary farming settlements in the Middle East, where they have been observed in large numbers within the permanent house and storage structures, e.g. at Çatalhöyük in Turkey (Jenkins, 2012:397; Jenkins, 2009; O'Connor, 2013:49, 128). In addition, studies from modern Turkey have shown that commensal rodents can consume or damage 5–15% of harvested and stored crops (McCormick, 2003), so the large quantity of rodent bone in and around the fermentation pit could even be reflected in the decision to stop fermenting fish there, as suggested by the deposition of a fish-skeleton patterned ornate bone knife on top of the fermentation pit (Boethius, 2016): increasing destruction of the fermenting fish by rodents could have ended the usefulness of that location for the pit. Eight more small fragments of other fish skeleton knives were also found during the excavation (Fig. 13), possibly indicating the presence of other abandoned fermentation facilities at the site.

3.2. Environmental prerequisites

Norje Sunnansund is located in an ecotone environment, which makes the site a typical Mesolithic settlement, when occupation

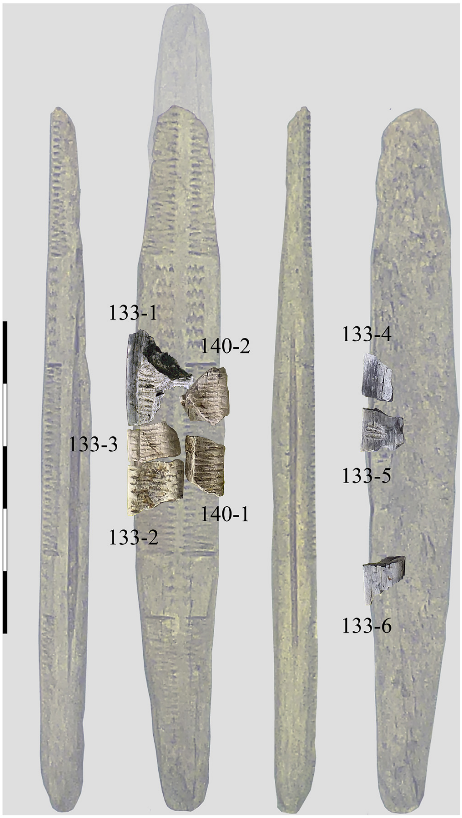


Fig. 13. The fish skeleton bone knife, and small fragments from similar knives found in other areas of the excavation site. Picture by Éva David (David and Kjällquist, in press).

sites are often located at the border of different biomes. The importance of locating settlements on lake borders cannot be understated, because of the exceptional bioproductivity of such areas (Bos et al., 2006; Mellars and Dark, 1998), and emphasizes the need to use the environment in an optimal way. In this type of environment there is access to a large set of faunal and plant resources. In the case of Norje Sunnansund, this includes vegetation zones on the shores of the different water bodies and pine forest on the slopes of Ryssberget and the surrounding flatlands. However, the most striking feature of Norje Sunnansund's location is the access to three diverse sources of water (lake, stream and sea), which facilitated fishing and hunting for seals during different parts of the year. The possibility of exploiting different subsistence resources during different parts of the year is also something that has been stressed as one of the prerequisites for sedentism in more recent foraging societies (Rowley-Conwy, 1983).

3.2.1. Storage facilities

The location of a settlement in a diverse environment is a classic risk-reducing strategy when living a sedentary lifestyle (Rowley-Conwy and Zvelebil, 1989). The basics of the strategy are that you use as many local resources as possible and strive to create a surplus storage; thereby, if one of the resources should fail there is a back-up ready to be used. Utilizing the environment in this way is a common strategy for coping with seasonal variations and short-term crises in a well-functioning foraging society (Rowley-Conwy and Zvelebil, 1989). The creation of storage facilities is also well known in ethnographic accounts of foraging societies (Eidlitz, 1969; Minc and Smith, 1988) and is considered to be common practice (Ingold, 1983).

Because fish storage was practiced at Norje Sunnansund (Boethius, 2016), following the arguments of Rowley-Conwy and Zvelebil (1989) this implies a delayed-return economy. Although food can be stored in the landscape without constant monitoring (Binford, 1978; Ingold, 1983), indications of a prolonged stay at the site suggest that this was not the case. Moving food reserves often requires a great deal of effort and is often impractical when larger boats and effective trading routes are not available (Rowley-Conwy and Zvelebil, 1989); thereby, the presence of storage at Norje Sunnansund implies a more sedentary lifestyle.

3.2.2. Seasonality indicators

It was possible to investigate the site's seasonality using a variety of different indicators and, as illustrated in Fig. 14, the site appeared to have been inhabited throughout the year from late summer to late spring, although interpretation should be made with some caution due to the conflating of the different phases. Poor organic preservation from the youngest phase have resulted in large taphonomic losses, i.e. disintegration of juvenile bones, most fish bones and plant remains. Consequently, most of the seasonality indicators are from the oldest phase and cannot be studied in the youngest layer. The seasonality indicators were the presence of ringed seal, grey seal and roe deer fetuses, young seal calves, juvenile wild boars, red deer antlers attached to skulls, only fully grown small fur-game species, a wide array of different migratory bird species, intensified roach fishing and the presence of a fish fermentation feature. Further evidence was provided by wild cherry (*Prunus avium*) and bird cherry (*Prunus padus*) cores, hawthorn (*Crataegus*), raspberry (*Rubus idaeus*) and dewberry (*Rubus caesius*) seeds and hazel (*Corylus avellana*) and alder (*Alnus*) catkins (Kjällquist et al., 2016; Lagerås et al., forthcoming).

As indicated in Fig. 14, the relatively large number of seasonality indicators for the coldest part of the year is interesting and suggests an intensification of site use during the winter period. Norje Sunnansund is the only known settlement from Early Mesolithic southern Scandinavia with typically winter seasonal indicators. Almost all other southern Scandinavian sites with preserved organic material from this period are inland sites (apart from Huseby Klev and Balltorp on the west coast of Sweden) and display exclusively summer seasonal indicators (Carter, 2001; Price, 2015:115; Rowley-Conwy, 1993), implying that they might have been occupied only during a limited part of the year, albeit for many reoccurring visits. This distribution is probably because almost the entire European west paleo-coastline, from the Paleolithic period until the beginning of the Middle Mesolithic period, is under water as a result of the transgression following the melting of the ice after the last ice age; the north-west coast of Scandinavia is the exception to this because here the isostatic land rise have equaled the sea level rise, which have made parts of the paleo-coastline from this period visible today (Riede, 2014:567). Therefore, Norje Sunnansund has the potential to increase our understanding and interpretation of the Early Mesolithic period by adding both the dimension of a winter settlement and the dimension of a site located next to a major water body that is not submerged beneath the sea.

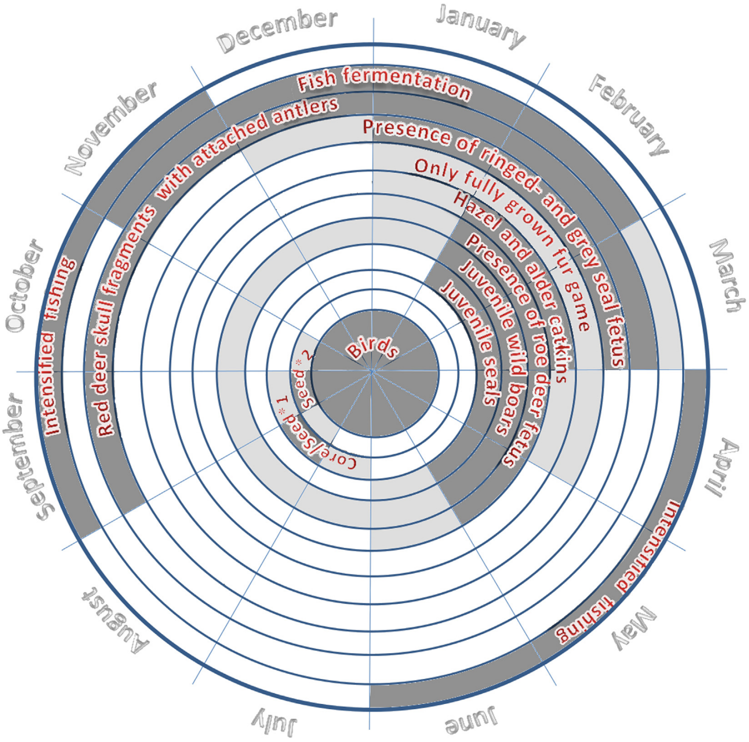


Fig. 14. Seasonality indicators from Norje Sunnansund. Dark grey shows likely seasonality indicators, light grey shows conceivable seasonality indicators.

4. Conclusion

The site of Norje Sunnansund displays a wide array of evidence linking it with a sedentary lifestyle. Fish was the main dietary component and would probably have been a constant and predictable food source at Norje Sunnansund. All year-round fishing was possible because of the three different water bodies surrounding the site, which yielded different catches depending on when and where the fishing took place. Fishing was intensified during the autumn, when large amounts of roach were caught and then fermented during the winter, and during the spring, when fish aggregated for spawning activities. Fish were therefore used to provide both a constant supply of fresh food and a source of stored surplus food to prevent periods of famine. The amount of fish caught at the site was massive and enough to feed a large number of people during most of the year (Boethius, 2017b). The large amounts of caught fish and the means to prepare and store them imply that the inhabitants used the site as a permanent settlement. Furthermore, the rodent spatial distribution suggests that the fish fermentation facility was a permanent structure. Even though the rodent species present in Scandinavia 9000 years ago are not commonly recognized today as commensal species, their spatial distribution at Norje Sunnansund suggests that it is possible for non-commensal species to behave commensally in the absence of competition. Because of the required investment in time and effort to manufacture the equipment to facilitate large fish catches, and because the fermentation process itself is time consuming, the use of the settlement seems to fit well with an economy based on delayed-return principles.

The evidence from ungulate hunting can also be linked directly to a delayed-return economy; in particular, fully grown but not sexually mature red deer were selectively hunted. This hunting pattern ensures a continued restocking of the animals at the same time as maximizing the amount of meat and raw materials gained from them. However, the indications of a conservative hunt are controversial, exemplified by the debate of the ‘ecological Indian’. Krech states that native Americans display no compelling evidence of ecological living and conservation of the environment prior to European contact but much evidence of the opposite (Krech, 2000). Smith and Wishnie (2000) examined the evidence of conservation on a global scale and concluded that there is little evidence of indigenous people practicing environmental conservation and, where it can be seen, it is rarely displayed as animal prey conservation. As this view has come to dominate the debate during the last decade, and as there is limited evidence in the anthropologic literature to suggest otherwise (Hames, 2007), it would be irrational to argue for a global environmental conservation approach by foraging people. The conservation of young red deer in the Norje Sunnansund assemblage does not imply a ‘harmony with nature’ lifestyle among Early Mesolithic foragers. Aurochs and elk are almost absent from the bone assemblage, possibly as a result of prior over-exploitation, and seals were hunted indiscriminately during the late winter and early spring, with the hunt focusing on lactating females and their cubs, with no regard to age, sex or whether the females were in-calf. Nevertheless, the hunting of red deer could be considered sustainable and fits the ecological definition of conservation as a 'costly sacrifice of immediate rewards in return for delayed ones' (Hames, 2007). However, and importantly, it was not done to maintain red deer as the basis of a subsistence strategy. If that had been the case, it is unlikely that a conservative hunt would have been practiced; if a group of people was at risk of starvation, they would kill and eat whatever was available, but if killing in a suboptimal way would subject the group to risk later, a conservative approach might be considered. As the large amounts of caught fish and the means to store it indicate a primarily fish diet, it appears that the red deer were hunted for both meat and other raw materials. The body of a fully grown red deer yields much more meat, larger skins, thicker tendons and larger and stronger bones for making tools than subadult, smaller individuals. Therefore, a kill-off pattern representing fully grown red deer not yet in their prime would be optimal as it would provide the best raw material while at the same time conserving the reproductive animals. Even though a kill-off sex ratio is missing and the interpretation of a completely optimized hunt is not possible, the evidence for a selective red deer hunt seems compelling. Large fur-game species appear, similar to red deer, selectively hunted when fully grown, even though the available data is limited and taphonomic biases, concerning the preservation of juvenile bones, can have affected the interpretation. This suggest that selective hunting strategies can have been used to target the largest individuals supplying the largest pelts while, at the same time, act to reduce competition from adult predators in the areas surrounding the settlement. The inhabitants of Norje Sunnansund therefore appeared to practice a delayed-return strategy of managing their resources similar to pastoralist behavior, not commonly associated with foraging economies (Ingold, 1983:565).

It is currently unclear whether Norje Sunnansund should be considered an exceptional or a common Early Mesolithic winter/all-year round settlement. Contemporaneous settlement permanence has been suggested outside of Scandinavia, e.g. at Star Carr (Conneller et al., 2012). However, on a more local basis it is unlikely that this matter will be completely resolved until another Early Mesolithic winter settlement/coastal site with preserved organic material is found or until further excavations on known Early Mesolithic sites can be conducted (including on Norje Sunnansund as only small parts of the original site has been excavated). Overall, the material from Norje Sunnansund indicates an Early Mesolithic delayed-return sedentary lifestyle in southern Scandinavia, with subsistence strategies based on storing surplus while at the same time exploiting different aspects of the immediate environment. If Norje Sunnansund is put in the context of wider settlement systems, as defined by Rowley-Conwy (1993), the evidence fit Kent (1989)'s definition of a sedentary society. Albeit a society that has not yet experienced over-crowding and where indications of seasonal occupation decline during the summer is a part of the annual cycle, as illustrated by summer seasonality indications on Norje Sunnansund being limited to the presence of certain bird species and to the cores and seeds from various plants while the other seasons show a greater seasonality indication diversity. The contemporaneous inland sites, all with exclusively summer indicators, therefore could have functioned as seasonal hunting grounds, with smaller hunting parties scattered across the landscape for hunting forays during the summer and into the autumn, after which they rejoined those who stayed at the permanent coastal settlement. This bears some resemblance to previous models where winter camps have been suggested as aggregated settlements located on the coast (Blankholm, 1996:125-26; Larsson, 1980). However, with the crucial evidence provided by the massive amount of fish, evidence of delayed-return storage facilities, all year-round seasonal indicators, a selective red deer hunt and rodent intrusions in permanent structures, Norje Sunnansund implies that coastal sites did not function as a seasonal stop along transient routes, but instead as a permanent settlement from which summer excursions by smaller groups of people were undertaken. Even though it is not known how representative Norje Sunnansund is compared with other contemporaneous coastal settlements, the presence of at least one sedentary society indicates the beginning of a revolution that ultimately led to the large and widespread, non-egalitarian, socially stratified, aquatically dependent and sedentary communities that can be observed in the Late Mesolithic Ertebølle culture. The knowledge that aquatically dependent, sedentary communities had existed for thousands of years prior to the development of the Neolithic lifestyle indicates that the Mesolithic communities in Scandinavia had experienced a long period of population growth, as suggested by the fact that the only way to increase populations in cold environments is through the exploitation of aquatic resources (Binford, 2001:216). Following thousands of years of exploiting aquatic resources, by the end of the Mesolithic era southern Scandinavia could have been densely populated, even crowded, and as such these communities could indeed be compared with the native American aquatically dependent communities of the north-west coast prior to European contact. Furthermore, a long tradition of aquatically reliant sedentary Scandinavian foragers explains the temporal boundary of the agricultural frontier, for as long as a millennia, when the Neolithic lifestyle reached the southern Baltic (Cummings et al., 2014) and why Scandinavians remained foragers significantly longer than settlements further south: they were numerous enough to withstand contingent territorial claims from advancing farmers and content enough with their lifestyle not to change it.

Acknowledgements

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Appendix

The appendices includes number of identified specimens (NISP), minimum number of individuals (MNI), Weight, number of unidentified specimens (NUSP) and number of specimens (NSP) for each animal class found at Norje Sunnansund. The data is presented within the different contexts in addition to the total value used in this study. The old phase includes the oldest cultural layer and some minor features associated with the old phase, but not associated with the fermentation facility. The fermentation facility is contemporaneous with the old phase and includes the finds within the main fermentation facility and its surrounding postholes and stakeholes. The young phase includes the youngest cultural layer. The fluvial mixed layer is a layer deposited in the water close to the beach; it is a mix of both land layers and thus a temporal mix of both settlement phases. MNI have been calculated using overlapping parts of the most frequently occurring element. Age differences have not been considered while calculating MNI. The total MNI is not the sum of the different context MNI but a derived calculation. In the main paper total NISP has been used as the means of quantification.

Appendix Table 1
The mammal bones from Norje Sunnansund.

Mammals (Mammalia)																			
Family	Species	NISP					MNI					Weight (g)					Total		
		Old phase	Fermentation facility	Young phase	Fluvial waste layer	Preliminary excavation	Old phase	Fermentation facility	Young phase	Fluvial waste layer	Preliminary excavation	Old phase	Fermentation facility	Young phase	Fluvial waste layer	Preliminary excavation	NISP	MNI	Weight (g)
Ungulates																			
Cervidae	Red deer *(Cervus elaphus)*	194		63	113	3	3		1	3	1	1962		273,3	1601,7	14,2	373	5	3851,6
	Roe deer *(Capreolus capreolus)*	218	1	23	29		3		1	2		420,3	0,6	37,8	23,7		271	4	482,4
	Elk *(Alces alces)*	4		4	11		1		1	2		79,4		53,1	61,8		19	2	194,3
	Cervidae indet.	24		2	3	2	n/a					63,4		4,7	36,5	4,9	31	n/a	109,5
Bovidae	Aurochs *(Bos primigenius)*	30			2		2			2		639,4			251,7		32	2	891,1
Suidae	Wild boar *(Sus scrofa)*	220	2	49	53	7	3	1	3	2	1	762,3	17,1	117,5	171,2	35,8	331	4	1103,9
Seals																			
Phocidae	Grey seal *(Halichoerus grypus)*	57	1	10	9		7	1	2	1		168,4	0,8	30,4	26,1		77	9	225,7
	Ringed seal *(Pusa hispida)*	27	1	7	6	1	2	1	2	1	1	30,1	0,74	12,8	22,7	5,1	42	3	71,44
	Phocidae indet.	118	16	17	21		4	1	1	1		136,1	7,96	21,7	21,2		172	5	186,96
Animals hunted for fur																			
Ursidae	Brown bear *(Ursus arctos)*	11		4	4		1		1	1		29,7		31,7	6,6		19	2	68
Canidae	Wolf *(Canis lupus)*	3		3	8		1		1	2		5,5		7	70,7		14	2	83,2
	Red fox *(Vulpes vulpes)*	12		4	5	1	1		1	1	1	12,1		1,8	3,1	0,3	22	2	17,3
	Dog *(Canis familiaris)*	22		3	7		1		1	1		28,1		3,6	11,3		32	2	43
	Canidae indet.	6		1	4		n/a					8,3		1,2	1,6		11	n/a	11,1
Mustelidae	Badger *(Meles meles)*	23		6			2		1			9,8		5,6			29	2	15,4
	Otter *(Lutra lutra)*	21		11	4		1		2	1		9,1		12,4	1,9		36	2	23,4
	Pine marten *(Martes martes)*	32		5	4	1	2		1	1	1	8,1		1,3	0,5	1,3	42	3	11,2
	European polecat *(Mustela putorius)*	1					1					0,9					1	1	0,9
Felidae	Wild cat *(Felis silvestris)*	6		1	2		1		1	1		3		0,2	0,7		9	1	3,9
	Carnivora indet.	5			1		n/a					3,9			0,2		6	n/a	4,1
Erinaceidae	European hedgehog *(Erinaceus europaeus)*	7					3					2,3					7	3	2,3
Leporidae	Mountain hare *(Lepus timidus)*	1					1					0,5					1	1	0,5

(*continued on next page*)

Appendix Table 1 (*continued*)

Mammals (Mammalia)																			
Family	Species	NISP					MNI					Weight (g)					Total		
		Old phase	Fermentation facility	Young phase	Fluvial waste layer	Preliminary excavation	Old phase	Fermentation facility	Young phase	Fluvial waste layer	Preliminary excavation	Old phase	Fermentation facility	Young phase	Fluvial waste layer	Preliminary excavation	NISP	MNI	Weight (g)
Castoridae	Beaver *(Castor fiber)*	9		4	3	1	2		1	1	1	47,5		4,3	1,4	1,3	17	2	54,5
Sciuridae	Red squirrel *(Sciurus vulgaris)*	46	1	7	3		6	1	2	1		6	0,06	0,7	0,3		57	8	7,06
Rodents																			
Cricetidae	Water vole (*Arvicola amphibius*)	36	13	3	11	9	10	2	1	3	1	8,2	1,72	0,3	1,9	0,4	72	12	12,52
	Field *(Microtus agrestis)*	6	2		1	5	3	1		1	1	0,6	0,2		0,1	0,1	14	5	1
Muridae	Yellow-necked mouse (*Apodemus flavicollis*)	7	2				4	1				1,3	0,21				9	4	1,51
	Rodent indet. (Rodentia)	109	12	8	29		n/a					8,6	0,85	0,9	2,7		158	n/a	13,05
Humans																			
Hominidae	Human *(Homo sapiens)*	6		9	20	1	1		5	2	1	13,9		11,2	100,3	2,1	36	5	127,5
Total mammals																			
NISP	Sum of identified mammals	1261	51	244	353	29	66	9	29	30	8	4469	30,24	633,5	2419,9	56,4	1940	91	7618,34
NUSP	Mammal indet. (Mammalia)	11,467	68	2538	2295	60	n/a					3444	11,42	1079	789,8	31,4	16,428	n/a	5356,32
NSP	Number of specimens	12,728	119	2782	2648	89	n/a					7914	41,66	1713	3209,7	87,8	18,368	n/a	12,974,66

Appendix Table 2
The bird bones from Norje Sunnansund.

Birds (Aves)

Family	Species	NISP					MNI					Weight (g)					Total		
		Old phase	Fermentation facility	Young phase	Fluvial waste layer	Preliminary excavation	Old phase	Fermentation facility	Young phase	Fluvial waste layer	Preliminary excavation	Old phase	Fermentation facility	Young phase	Fluvial waste layer	Preliminary excavation	NISP	MNI	Weight (g)
Anatidae	Northern shoveler (*Anas clypeata*)	3		1			1		1			0,8		0,2			4	2	1
	Eurasian wigeon (*Anas penelope)*	1			1		1			1		0,4			0,2		2	1	0,6
	Mallard (*Anas platyrhynchos)*	9		4			2		1			9,4		2,6			13	2	12
	Garganey (*Anas querquedula)*	1					1					0,5					1	1	0,5
	Northern pintail *(Anas acuta)*	1					1					0,3					1	1	0,3
	Common pochard (*Aythya ferina)*	1					1					0,2					1	1	0,2
	Tufted duck (*Aythya fuligula)*	3			1		1			1		1,2			1		4	2	2,2
	Greater scaup (*Aythya marila)*	2					1					1,3					2	1	1,3
	Common goldeneye (*Bucephala clangula)*	4					1					1,5					4	1	1,5
	Long tailed duck (*Clangula hyemalis*)	1					1					0,2					1	1	0,2
	Common eider (*Somateria mollissima)*	1					1					1					1	1	1
	Velvet scoter (*Melanitta fusca)*	5	1		1		2	1		1		7,5	1		0,3		7	2	8,8
	Common scoter *(Melanitta nigra)*			1					1					1,5			1	1	1,5
	Common merganser (*Mergus merganser)*	4	2		1		1	1		1		3,3	1,1		1		7	1	5,4
	Red-breasted merganser *(Mergus serrator*)	2					1					0,4					2	1	0,4
	Greylag goose (*Anser anser)*	6			2		1			1		6,8			5		8	1	11,8
	Bean goose (*Anser fabalis)*	1			1		1			1		5			2		2	1	7
	Anserini indet.	2					1					1,5					2	1	1,5
	Anatidae indet.	7		1			1		1			2,5		0,2			8	1	2,7
Podicipedidae	Great crested grebe *(Podiceps cristatus)*			2	1				1	1				2,3	1,6		3	1	3,9
	Red-necked grebe *(Podiceps grisegena)*				1					1					1		1	1	1
Gaviidae	Black-throated loon (*Gavia arctica)*	3					1					5					3	1	5
	Red-throated loon (*Gavia stellata)*	2		1			1		1			2		0,3			3	1	2,3

(*continued on next page*)

Appendix Table 2 (*continued*)

Birds (Aves)

Family	Species	NISP					MNI					Weight (g)					Total		
		Old phase	Fermentation facility	Young phase	Fluvial waste layer	Preliminary excavation	Old phase	Fermentation facility	Young phase	Fluvial waste layer	Preliminary excavation	Old phase	Fermentation facility	Young phase	Fluvial waste layer	Preliminary excavation	NISP	MNI	Weight (g)
Phalacrocoracidae	Great cormorant (*Phalacrocorax carbo)*	7			2	1	1			1	1	10,6			3	1,3	10	1	14,9
Ardeidae	Grey heron (*Ardea cinerea)*	2					1					1,2					2	1	1,2
Corvidae	Carrion crow (*Corvus corone)*	4	1				1					1,9	0,2				5	1	2,1
	Spotted nutcracker *(Nucifraga caryocatactes)*		1					1					0,13				1	1	0,13
	Corvidae indet.	4					3					2,5					4	3	2,5
Phasianidae	Western capercaillie (*Tetrao urogallus)*	1					1					1					1	1	1
Accipitridae	Red kite (*Milvus milvus)*	1					1					0,3					1	1	0,3
Accipitridae	White-tailed eagle (*Haliaeetus albicilla)*	1					1					2					1	1	2
Total birds																			
NISP	Sum of identified bird specimens	79	5	10	11	1	31	3	6	9	1	70,3	2,43	7,1	15,1	1,3	106	37	96,23
NUSP	Indeterminable bird specimens (Aves)	62	2	2	4	2	n/a					17,6	0,09	0,5	3,9	1,8	70	n/a	23,89
NSP	Number of bird specimens	141	7	12	15	3	n/a					87,9	2,52	7,6	19	3,1	176	n/a	120,12

Appendix Table 3

The fish bones from Norje Sunnansund. [1]Quantifications are based on a partial analysis of the entire fish bone assemblage. The analyzed fish bones were randomly selected from different areas of the three cultural layers while the fish bone remains in the fermentation facility was comprehensively analyzed. Dependent on phase the proportion of analyzed fish bones vary: old phase ≈ 6,9%, fermentation facility 100%, young phase ≈ 39%, fluvial mixed layer ≈ 7%. [2]MNI in the fermentation facility have been derived without including the fish bones within the postholes, stakeholes or the eastern part of the feature sieved using a 5 mm mesh (for further specification see Boethius, 2016, 2017b). [3]No attempts have been made to derive the total fish MNI.

Fish (Pisces)																			
Family	Species	NISP					MNI					Weight (g)					Total		
		Old phase	Fermentation facility	Young phase	Fluvial waste layer	Preliminary excavation	Old phase	Fermentation facility	Young phase	Fluvial waste layer	Preliminary excavation	Old phase	Fermentation facility	Young phase	Fluvial waste layer	Preliminary excavation	NISP	MNI	Weight (g)
Cyprinidae	Cyprinids indet. (Cyprinidae)	3162	7418	51	73	4	91	213	4	3	1	99,67	192,43	3,3	2,9	0,3	10,708	n/a*	298,599
	Cyprinids (Rutilus/Leuciscus)	127	34									4,1	1,2				161	n/a*	5,3
	Roach *(Rutilus rutilus)*	347	665	1	3							24,7	36,12	0,2	0,3		1016	n/a*	61,32
	Silver bream *(Blica bjoerkna)*		3										0,2				3	n/a*	0,2
	Bream (*Abramis brama)*	6	13			1						0,6	1,06			0,3	20	n/a*	1,96
	European chub *(Squalius cephalus)*	2	4									0,2	0,32				6	n/a*	0,52
	Crucian carp *(Carassius carassius)*	2	5		1							0,2	0,4		0,1		8	n/a*	0,7
	Rudd (*Scardinius erythrophthalmus)*	3	9	1								0,5	0,88	0,2			13	n/a*	1,58
	Dace *(Leuciscus leuciscus)*	2	9									0,2	0,26				11	n/a*	0,46
	Tench *(Tinca tinca)*	5	13		1							0,5	1,4		0,1		19	n/a*	2
	Bleak *(Alburnus alburnus)*	1	5									0,1	0,32				6	n/a*	0,42
	Ide *(Leuciscus idus)*	2	5									0,2	0,5				7	n/a*	0,7
Percidae	Perch *(Perca fluviatilis)*	926	1327	122	201	152	35	35	5	10	6	39,66	31,87	6,5	8,6	5,1	2728	n/a*	91,73
	Pike perch *(Sander lucioperca)*	20	5	9	19		1	1	1	2		2,1	0,24	1,7	1,9		53	n/a*	5,94
	Ruffe *(Gymnocephalus cernua)*	1	34				1	1				0,1	0,3				35	n/a*	0,4
	Percidae indet.		13					1					0,5				13	n/a*	0,5
Esocidae	Pike *(Esox lucius)*	419	588	37	51	3	10	11	2	5	1	50,47	51,67	6,6	7,1	0,5	1098	n/a*	116,34
Lotidae	Burbot *(Lota lota)*	25	55	1	2		1	4	1	1		1,8	3,05	0,1	0,2		83	n/a*	5,15
Salmonidae	Arctic char *(Salvelinus alpinus)*		3					1					0,09				3	n/a*	0,09
	Whitefish (Coregonus sp.)	11	19	1	1		1	1	1	1		0,9	1,3	0,1	0,1		32	n/a*	2,4
	Trout *(Salmo trutta)*	1					1					0,1					1	n/a*	0,1
	Salmonids indet. (Salmonidae)	5	2				1	1				0,5	0,21				7	n/a*	0,71
	Salmon *(Salmo salar)*				1					1					0,1		1	n/a*	0,1
Anguillidae	Eel *(Anguilla anguilla)*	58	79		1		2	2		1		2,2	1,6		0,2		138	n/a*	4
Osmeridae	Smelt *(Osmerus eperlanus)*		10					2					0,43				10	n/a*	0,43

(*continued on next page*)

Appendix Table 3 (*continued*)

Fish (Pisces)																			
Family	Species	NISP					MNI					Weight (g)					Total		
		Old phase	Fermentation facility	Young phase	Fluvial waste layer	Preliminary excavation	Old phase	Fermentation facility	Young phase	Fluvial waste layer	Preliminary excavation	Old phase	Fermentation facility	Young phase	Fluvial waste layer	Preliminary excavation	NISP	MNI	Weight (g)
Total pisces																			
NISP	Sum of identified fish	5125	10,318	223	354	160	144	273	14	24	8	228,8	326,35	18,7	21,6	6,2	16,180	n/a	601,649
NUSP	Indeterminable fish specimens (pisces)	1010	3186	22	110	86	n/a					28,13	52,75	1,7	3,3	1,2	4414	n/a	87,08
NSP	Number of fish specimens	6135	13,504	245	464	246	n/a					256,9	379,1	20,4	24,9	7,4	20,594	n/a	688,729

References

Aaris-Sørensen, K., 1978. Knoglematerialet fra den mellemneolitiske boplads ved Korsnäs, Riksantikvarieämbetet och Statens Historiska Museer Rapport (Stockholm).

Albrethsen, S.E., Brinch Petersen, E., 1976. Excavation of a Mesolithic cemetery at Vedbæk, Denmark. Acta Archaeol. 47, 1–28.

Almkvist, L., Olsson, M., Soderberg, S., 1980. Sälar i Sverige. Svenska Naturskyddsföreningen, Stockholm. ISBN 91-558-5171-1 (in Swedish).

Alvard, M.S., 1993. Testing the "ecologically noble savage" hypothesis: interspecific prey choice by Piro hunters of Amazonian Peru. Hum. Ecol. 21, 355–387.

Anderson, K., 2005. Tending the Wild: Native American Knowledge and the Management of California's Natural Resources. University of California Press, Berkeley.

Andersson, E.I., 2006. Kläderna och människan i medeltidens Sverige och Norge. Göteborg University.

Andrén, T., Björck, S., Andrén, E., Conley, D., Zillén, L., Anjar, J., 2011. The Development of the Baltic Sea Basin during the Last 130 ka, the Baltic Sea Basin. Springer, pp. 75–97.

Anticimex, 2013. Facts on Rats and Resistance (Stockholm).

Antonsson, K., 2006. Holocene Climate in Central and Southern Sweden: Quantitative Reconstructions from Fossil Data. Uppsala University, Uppsala.

Arnold, J.E., 1996. The archaeology of complex hunter-gatherers. J. Archaeol. Method Theory 3, 77–126.

Aswani, S., 1998. Patterns of marine harvest effort in southwestern New Georgia, Solomon Islands: resource management or optimal foraging? Ocean Coast. Manag. 40, 207–235.

Bar-Yosef, O., Belfer-Cohen, A., 1989. The origins of sedentism and farming communities in the Levant. J. World Prehistory 3, 447–498.

Battley, P.F., 2006. Consistent annual schedules in a migratory shorebird. Biol. Lett. 2, 517–520.

Bay-Petersen, J., 1978. Animal exploitation in mesolithic Denmark. In: Mellars, P.A. (Ed.), The Early Postglacial Settlement of Northern Europe. Duckworth, London, pp. 115–146.

Bender, B., 1978. Gatherer-hunter to farmer: a social perspective. World Archaeol. 10, 204–222.

Berkes, F., Turner, N.J., 2006. Knowledge, learning and the evolution of conservation practice for social-ecological system resilience. Hum. Ecol. 34, 479–494.

Binford, L.R., 1968. Post-pleistocene adaptations. In: Binford, L.R., Binford, S.R. (Eds.), New Perspectives in Archeology. Aldine, Chicago, pp. 313–341.

Binford, L.R., 1978. Nunamiut Ethnoarchaeology. Academic Press New York.

Binford, L.R., 1981. Bones: Ancient Men and Modern Myths. Academic Press, New York.

Binford, L.R., 2001. Constructing Frames of Reference: an Analytical Method for Archaeological Theory Building Using Ethnographic and Environmental Data Sets. University of California Press, Berkeley.

Blankholm, H.P., 1996. On the Track of a Prehistoric Economy: Maglemosian Subsistence in Early Postglacial South Scandinavia. Aarhus Universitetsforlag.

Boethius, A., 2016. Something rotten in Scandinavia: the world's earliest evidence of fermentation. J. Archaeol. Sci. 66, 169–180.

Boethius, A., 2017a. Huseby klev and the quest for pioneer subsistence strategies: diversification of a maritime lifestyle. In: Persson, P., Skar, B., Breivik, H.M., Riede, F., Jonsson, L. (Eds.), The Ecology of Early Settlement in Northern Europe - Conditions for Subsistence and Survival. Equinox, Sheffield (in press).

Boethius, A., 2017b. The use of aquatic resources by Early Mesolithic foragers in southern Scandinavia. In: Persson, P., Skar, B., Breivik, H.M., Riede, F., Jonsson, L. (Eds.), The Ecology of Early Settlement in Northern Europe - Conditions for Subsistence and Survival. Equinox, Sheffield (in press).

Bos, J.A., Urz, R., 2003. Late Glacial and early Holocene environment in the middle Lahn river valley (Hessen, central-west Germany) and the local impact of early Mesolithic people—pollen and macrofossil evidence. Veg. Hist. Archaeobot. 12, 19–36.

Bos, J.A., van Geel, B., Groenewoudt, B.J., Lauwerier, R.C.M., 2006. Early Holocene environmental change, the presence and disappearance of early Mesolithic habitation near Zutphen (The Netherlands). Veg. Hist. Archaeobot. 15, 27–43.

Bosold, K., 1966. Geschlechts-und Gattungsunterschiede an Metapodien und Phalangen mitteleuropäischer (Wildwiederkäuer, München).

Boyd, B., 2006. On 'sedentism'in the Later Epipalaeolithic (Natufian) Levant. World Archaeol. 38, 164–178.

Bratlund, B., 1991. The bone remains of Mammals and birds from the Bjørnsholm Shell-mound: a preliminary report. J. Dan. Archaeol. 10, 97–104.

Briedermann, L., 1990. Schwarzwild (Dt. Landwirtschaftsverl., Berlin).

Brown, J.A., 1985. Long-term trends to sedentism and the emergence of complexity in the American midwest. In: Price, D.T., Brown, J.A. (Eds.), Prehistoric Hunter-gatherers: the Emergence of Cultural Complexity. Academic press, Orlando.

Burch, E., 2007. Rationality and Resource Use Among Hunters: Some Eskimo Examples. University of Nebraska, Lincoln.

Carter, R.J., 2001. Dental indicators of seasonal human presence at the Danish boreal sites of Holmegaard I, IV and V and mullerup and the Atlantic sites of Tybrind Vig and Ringkloster. Holocene 11, 359–365.

Clutton-Brock, T.H., Albon, S.D., 1989. Red Deer in the Highlands. Blackwell Scientific, Oxford.

Clutton-Brock, T.H., Guinness, F.E., 1982. Red Deer: Behavior and Ecology of Two Sexes. University of Chicago Press.

Clutton-Brock, T.H., Albon, S., Gibson, R., Guinness, F.E., 1979. The logical stag: adaptive aspects of fighting in red deer (Cervus elaphus L.). Anim. Behav. 27, 211–225.

Clutton-Brock, T.H., Albon, S.D., Guinness, F.E., 1986. Great expectations: dominance, breeding success and offspring sex ratios in red deer. Anim. Behav. 34, 460–471.

Conneller, C., Milner, N., Taylor, B., Taylor, M., 2012. Substantial settlement in the European early Mesolithic: new research at star Carr. Antiquity 86, 1004–1020.

Cucchi, T., Vigne, J.-D., Auffray, J.-C., Croft, P., Peltenburg, E., 2002. Introduction involontaire de la souris domestique (Mus musculus domesticus) à Chypre dès le Néolithique précéramique ancien (fin IX e et VIII e millénaires av. J.-C.). Comptes Rendus Palevol 1, 235–241.

Cummings, V., 2013. The Anthropology of Hunter-Gatherers: Key Themes for Archaeologists. Bloomsbury Academic, London.

Cummings, V., 2014. Hunter-gatherers in the post glacial world. In: Cummings, V., Jordan, P., Zvelebil, M. (Eds.), The Oxford Handbook of the Archaeology and Anthropology of Hunter-gatherers. Oxford University Press, Oxford.

Cummings, V., Jordan, P., Zvelebil, M., 2014. The Oxford Handbook of the Archaeology and Anthropology of Hunter-gatherers. OUP Oxford.

Curry-Lindahl, K., 1969. Fiskarna i färg, seventh ed. Almqvist & Wiksell, Stockholm.

Curry-Lindahl, K., 1988. Däggdjur. groddjur & kräldjur, Norstedt.

David, É., Kjällquist, M., 2017. Transmission of the Mesolithic Northeastern crafting tradition. The Norje Sunnansund style introduced in the Maglemosian area around 9.3 ka BP. In: Glørstad, H., Knutsson, K., Knutsson, H., Apel, J. (Eds.), The Technology of Early Settlement in Northern Europe - Transmission of Knowledge and Culture. Equinox, Sheffield (in press).

Davis, B., Brewer, S., Stevenson, A., Guiot, J., 2003. The temperature of Europe during the Holocene reconstructed from pollen data. Quat. Sci. Rev. 22, 1701–1716.

Degn, H.J., 1973. Systematic Position, Age Criteria and Reproduction of Danish Red Squirrels (Sciurus vulgaris L.).

Eidlitz, K., 1969. Food and Emergency Food in the Circumpolar Area. Almqvist & Wiksell, Uppsala.

Ekberg, B., Nilsson, L., 1994. Skånes fåglar i dag och i gången tid. Del 1 Lommar till och med alkor (Kristianstad).

Ekberg, B., Nilsson, L., 1996. Skånes fåglar i dag och i gången tid. Del 2 Stäpphöna till och med kornsparv (Kristianstad).

Ekman, S., 1910. Norrlands jakt och fiske. almqvist & Wiksells, Uppsala.

Elias, S., Schreve, D., 2007. Late Pleistocene megafaunal extinctions. In: Elias, S. (Ed.), Encyclopedia of Quaternary Science, vol. 4. Elsevier Science Publishers, Amsterdam, pp. 3202–3217.

Enghoff, I.B., 2011. Regionality and Biotope Exploitation in Danish Ertebølle and Adjoining Periods. Det Kongelige Danske Videnskabernes Selskab, Copenhagen.

Ericson, P.G., Storå, J., 1999. A manual to the Skeletal Measurements of the Seal Genera Halichoerus and Phoca (Mammalia: Pinnipedia). Department of Vertebrate Zoology, Swedish Museum of Natural History, Stencil, Stockholm.

Eriksson, M., Magnell, O., 2001. Det djuriska Tågerup. Nya rön kring Kongemose-och Erteböllekulturens jakt och fiske. In: Karsten, P., Knarrström, B. (Eds.), Tågerup. Specialstudier. UV Syd, Avd. för arkeologiska undersökningar, Lund, pp. 156–237.

Erlandson, J.M., Rick, T.C., 2008. Archaeology, marine ecology, and human impacts on marine environments. In: Erlandson, J.M., Rick, T.C. (Eds.), Human Impacts on Ancient Marine Ecosystems: a Global Perspective, pp. 1–19.

Flannery, K., 1969. Origins and ecological effects of early domestication in Iran and the Near East. In: Ucko, P.J., Dimbleby, G. (Eds.), The Domestication and Exploitation of Plants and Animals. Aldine Publishing Co, Chacago, pp. 73–100.

Fleitmann, D., Mudelsee, M., Burns, S.J., Bradley, R.S., Kramers, J., Matter, A., 2008. Evidence for a widespread climatic anomaly at around 9.2 ka before present. Paleoceanography 23, 1–6.

Hadevik, C., Hammarstrand Dehman, K., Serlander, D., 2008. Arkeologiska förundersökningar i form av schaktningsövervakning 2003–2007 Malmö C Nedre – i samband med byggandet av tunnel och ny stationsbyggnad, Enheten för Arkeologi Rapport 2008:030, Malmö.

Hames, R., 2007. The ecologically noble savage debate. Annu. Rev. Anthropol. 36, 177–190.

Hansson, A., Nilsson, B., Sjöström, A., Björck, S., Holmgren, S., Linderson, H., Magnell, O., Rundgren, M., Hammarlund, D., 2016. A submerged Mesolithic lagoonal landscape in the Baltic Sea, south-eastern Sweden–Early Holocene environmental reconstruction and shore-level displacement based on a multiproxy approach. Quat. Int. http://dx.doi.org/10.1016/j.quaint.2016.07.059 (in press).

Härkönen, T., 2011. Klimatförändringar - så påverkas våra sälar. In: Lewander, M., Karlsson, M., Lundberg, K. (Eds.), Havet 2011 Om miljötillståndet i Våra Havsområden. Havsmiljöinstitutet.

Harris, D.R., 1977. Settling down: an evolutionary model for the transformation of mobile bands into sedentary communities. In: Friedman, J., Rowlands, M.J. (Eds.), The Evolution of Social Systems. Duckworth, London, pp. 401–417.

Hart, J., 1956. Seasonal changes in insulation of the fur. Can. J. Zool. 34, 53–57.

Hatting, T., 1969. Er bæverens tænder benyttet som redskaber i stenalderen i Danmark. Aarbøger Nordisk Oldkyndighed og Hist. 116–126.

Hayden, B., 2014. Social complexity. In: Cummings, V., Jordan, P., Zvelebil, M. (Eds.), The Oxford Handbook of the Archaeology and Anthropology of Hunter-gatherers. Oxford University Press, Oxford.

Heinrich, D., 1991. Untersuchungen an Skelettresten wildlebender Säugetiere aus dem mittelalterlichen Schleswig: Ausgrabung Schild 1971-1975 (Wachholtz).

Hesse, B., 1979. Rodent remains and sedentism in the Neolithic: evidence from tepe Ganj Dareh, western Iran. J. Mammal. 60, 856–857.

Hole, F., 1984. A reassessment of the Neolithic revolution. Paléorient 49–60.

Holst, D., 2010. Hazelnut economy of early Holocene hunter–gatherers: a case study from Mesolithic Duvensee, northern Germany. J. Archaeol. Sci. 37, 2871–2880.

Hunn, E., Johnson, D., Russell, P., Thornton, T., 2003. Huna Tlingit traditional environmental knowledge, conservation, and the Management of a “Wilderness” Park1. Curr. Anthropol. 44, S79–S103.

Huntley, B., 1993. Rapid early-Holocene migration and high abundance of hazel (Corylus avellana L.): alternative Hypotheses. In: Chambers, F.M. (Ed.), Climate Change and Human Impact on the Landscape : Studies in Palaeoecology and Environmental Archaeology. Springer, London, pp. 205–215.

Imby, L., 1987. Svenska fåglar: en fälthandbok. Prisma, Stockholm.

Ingold, T., 1983. The significance of storage in hunting societies. Man 18, 553–571.

Jarman, M.R., 1972. European red deer economies and the advent of the Neolithic. In: Higgs, E.S. (Ed.), Papers in Economic Prehistory, Studies by Members and Associates of the British Academy Major Research Project in the Early History of Agriculture. Cambridge University Press, Cambridge.

Jenkins, E.L., 2009. Unwanted Inhabitants? the Microfauna from Çatalhöyük and Pınarbası. VDM-Verlag.

Jenkins, E., 2012. Mice, scats and burials: unusual concentrations of microfauna found in human burials at the Neolithic site of Çatalhöyük, Central Anatolia. J. Soc. Archaeol. 12, 380–403.

Jensen, B., 2004. Nordens däggdjur, second ed. Prisma, Stockholm.

Jezierski, W., 1977. Longevity and mortality rate in a population of wild boar. Acta Theriol. 22, 337–348.

Jochim, M.A., 2011. The Mesolithic. In: Milisauskas, S. (Ed.), European Prehistory. Springer, New York, pp. 115–142.

Jonsson, L., 1996. Fauna och landskap i Göteborgstrakten under boreal tid. Djurbensfynden från den boreala kustboplatsen vid Balltorp, Mölndals kommun, Vg, Riksantikvarieämbetet UV Väst Rapport 1996.

Jonsson, L., 2014. Osteologisk analys – djurbenen från den preboreala kustboplatsen i Balltorp, RAÄ 182 i Mölndal, Västergötland. In: Johansson, G. (Ed.), En 10 000 år gammal boplats med organiskt material i Mölndal; Ytterligare en överlagrad Sandarnaboplats vid Balltorp Västra Götalands län, Västergötland, Mölndal stad, Balltorp 1:124, Mölndal 182, UV-väst rapport 2014, p. 91.

Jordan, P., Zvelebil, M., 2009. Ex Oriente Lux: the prehistory of hunter-gatherer ceramic dispersals. In: Jordan, P., Zvelebil, M. (Eds.), Ceramics before Farming: the Dispersal of Pottery Among Prehistoric Eurasian Hunter-gatherers. Left Coast Press, Walnut Creek.

Karsten, P., Knarrström, B., Hyll, S., 2003. The Tågerup Excavations. UV Syd, Avd. för arkeologiska undersökningar. Riksantikvarieämbetet, Lund.

Kelly, R.L., 1983. Hunter-gatherer mobility strategies. J. Anthropol. Res. 39, 277–306.

Kelly, R.L., 1992. Mobility/sedentism: concepts, archaeological measures, and effects. Annu. Rev. Anthropol. 21, 43–66.

Kelly, R.L., 2013. The Lifeways of Hunter-gatherers: the Foraging Spectrum. Cambridge University Press, Cambridge.

Kent, S., 1989. Cross-cultural Perceptions of Farmers as Hunters and the Value of Meat. Farmers as Hunters. Cambridge University Press, Cambridge, UK, pp. 1–17.

Kjällquist, M., Boethius, A., Emilsson, A., 2016. Norje Sunnansund : boplatslämningar från tidigmesolitikum och järnålder : särskild arkeologisk undersökning 2011 och arkeologisk förundersökning 2011 och 2012, Ysane socken, Sölvesborgs kommun i Blekinge län (Blekinge museum, Karlskrona).

Klein, R.G., 1969. Man and Culture in the Late Pleistocene: a Case Study. Chandler Publishing Company, San Francisco.

Klima, B., 1962. The first ground-plan of an upper Paleolithic loess settlement in Middle Europe and its meaning. In: Braidwood, R.J., Willey, G.R. (Eds.), Courses toward Urban Life: Archeological Considerations of Some Cultural Alternates. Aldine, Chicago, pp. 193–210.

Krech, S., 2000. The Ecological Indian: Myth and History. WW Norton & Company, New York.

Lagerås, P., Broström, A., Svensson, N.-O., 2017. Forthcoming. Insamling av ätliga växter och ved under mesolitikum. En diskussion baserad på makrofossil och träkol från västra Blekinge. In: Rudebeck, E., Anglert, M. (Eds.), Att leva vid Vesan. Arkeologi längs nya väg E22 i västra Blekinge. Blekinge museum, Karlskrona (in press).

Larsson, L., 1980. Some aspects of the Kongemose Culture of Southern Sweden. Meddelanden från Lunds univesitets Historiska museum 1979-80, pp. 5–22.

Larsson, L.e., 1988. The Skateholm Project I: Man and Environment. Almqvist & Wiksell International, Lund.

Legge, A.J., Rowley-Conwy, P., 1988. Star Carr Revisited: a Re-analysis of the Large Mammals. Centre for Extra-mural Studies. Birkbeck College, University of London, London.

Lindqvist, C., Possnert, G., 1997. The subsistence economy and diet at Jakobs/Ajvide and Stora Förvar, Eksta Parish and other Prehistoric Dwelling and burial sites on Gotland in long term perspective. In: Burenhult, G. (Ed.), Remote Sensing, vol. 1 (applied techniques for the study of cultural resources and the localization, identification and documentation of sub-surface prehistoric remains in Swedish archaeology, Tjörnarp).

Lowe, J.J., Walker, M.J., 2015. Reconstructing Quaternary Environments, 3. ed. Routledge, New York.

Lyman, R.L., 1991. Prehistory of the Oregon Coast. Academic, New York.

Magnell, O., 2006. Tracking Wild boar and Hunters: osteology of Wild boar in Mesolithic South Scandinavia. Lund University, Lund.

Magnell, O., 2017. Climate and wild game populations in South Scandinavia at

Holocene thermal maximum. In: Monks, G. (Ed.), Climate Change, Human Response and Zoorchaeology. Proceedings from the 11th International Conference of Archaeozoology, Paris 23-28th August, 2010. Vertebrate Paleobiology and Paleoanthropology Series. Springer Verlag in Print.

Marlowe, F.W., 2005. Hunter-gatherers and human evolution. Evol. Anthropol. Issues, News, Rev. 14, 54–67.

Mason, S., 2000. Fire and Mesolithic subsistence—managing oaks for acorns in northwest Europe? Palaeogeogr. Palaeoclimatol. Palaeoecol. 164, 139–150.

McCormick, M., 2003. Rats, communications, and plague: toward an ecological history. J. Interdiscip. Hist. 34, 1–25.

Meillassoux, C., 1973. On the Mode of Production of the Hunting Band. Oxford University Press.

Mellars, P.A., Dark, P., 1998. Star Carr in Context: New Archaeological and Palaeoecological Investigations at the Early Mesolithic Site of Starr Carr, North Yorkshire. McDonald Inst of Archeological.

Minc, L.D., Smith, K.P., 1988. The spirit of survival: cultural responses to resource variability in North Alaska. In: Halstead, P., O'Shea, J. (Eds.), Bad Year Economics: Cultural Responses to Risk and Uncertainty. Cambridge University Press, Cambridge, pp. 8–39.

Murdoch, J., 1892. Ethnological Results of the Point Barrow Expedition. Smithsonian Institution, Washington, DC.

Nilsson Stutz, L., 2003. Embodied Rituals and Ritualized Bodies: Tracing Ritual Practices in Late Mesolithic Burials. Lund University.

Nilsson Stutz, L., 2014. Mortuary practices. In: Cummings, V., Jordan, P., Zvelebil, M. (Eds.), The Oxford Handbook of the Archaeology and Anthropology of Hunter-gatherers. Oxford University Press, Oxford, pp. 712–728.

O'Connor, T., 1982. Animal bones from Flaxengate, Lincoln, C 870-1500 (London).

O'Connor, T., 2013. Animals as Neighbors: the Past and Present of Commensal Animals. Michigan State University Press.

Okarma, H., 1995. The trophic ecology of wolves and their predatory role in ungulate communities of forest ecosystems in Europe. Zesz. Probl. Postepow Nauk. Rol. 40, 335–386.

Pedersen, L., 1995. 7000 years of fishing: stationary fishing structures in the Mesolithic and afterwards. In: Fischer, A. (Ed.), Man and Sea in the Mesolithic : Coastal Settlement above and below Present Sea Level : Proceedings of the International Symposium, Kalundborg, Denmark 1993. Oxbow monograph, pp. 75–86. Oxford.

Price, T.D., 2015. Ancient Scandinavia: an Archaeological History from the First Humans to the Vikings. Oxford University Press, New York.

Price, T.D., Brown, J.A., 1985. Prehistoric Hunter-Gatherers: the Emergence of Cultural Complexity. Academic Press, Orlando.

Rasmussen, S.O., Vinther, B.M., Clausen, H.B., Andersen, K.K., 2007. Early Holocene climate oscillations recorded in three Greenland ice cores. Quat. Sci. Rev. 26, 1907–1914.

Riede, F., 2014. The resettlement of northern Europe. In: Cummings, V., Jordan, P., Zvelebil, M. (Eds.), The Oxford Handbook of the Archaeology and Anthropology of Hunter-gatherers. Oxford University Press, Oxford, pp. 556–581.

Rowley-Conwy, P., 1983. Sedentary hunters: the Ertebølle example. In: Bailey, G.N. (Ed.), Hunter-gatherer Economy in Prehistory. Cambridge University Press, Cambridge, pp. 1–26.

Rowley-Conwy, P., 1993. Season and reason: the case for a regional interpretation of Mesolithic settlement patterns. Archeol. Pap. Am. Anthropol. Assoc. 4, 179–188.

Rowley-Conwy, P., 2001. Time, change and the archaeology of hunter-gatherers: how original is the 'Original Affluent Society'. In: Panter-Brick, C., Layton, R.H., Rowley-Conwy, P. (Eds.), Hunter-gatherers: an Interdisciplinary Perspective. Cambridge University Press, Cambridge, p. 39.

Rowley-Conwy, P., Zvelebil, M., 1989. Saving it for later: storage by prehistoric hunter-gatherers in Europe. In: Halstead, P., O'Shea, J. (Eds.), Bad Year Economics: Cultural Responses to Risk and Uncertainty. Cambridge University Press, Cambridge, pp. 40–56.

Sahlins, M.D., 1972. Stone Age Economics. Transaction Publishers, London.

Seifert, T., Tauber, F., Kayser, B., 2001. A High Resolution Spherical Grid Topography of the Baltic Sea, second ed. Baltic Sea Science Congress, Stockholm 25-29. November 2001, Poster# 147. Online: www.iowarnemuende.de/iowtopo.

Serjeantson, D., 2009. Birds. Cambridge University Press, Cambridge.

Smith, E.A., Wishnie, M., 2000. Conservation and subsistence in small-scale societies. Annu. Rev. Anthropol. 493–524.

Soffer, O., 1985. The Upper Paleolithic of the Central Russian Plain. Academic Press, San Diego.

Sørensen, M., Rankama, T., Kankaanpää, J., Knutsson, K., Knutsson, H., Melvold, S., Eriksen, B.V., Glørstad, H., 2013. The first eastern migrations of people and knowledge into Scandinavia: evidence from studies of Mesolithic technology, 9th-8th millennium BC. Nor. Archaeol. Rev. 46, 19–56.

Storå, J., 2001. Reading Bones: Stone Age Hunters and Seals in the Baltic (Stockholm).

Sutton, M., 2016. Archaeology: the Science of the Human Past, fourth ed. Routledge, New York.

Tangri, D., Wyncoll, G., 1989. Of mice and men: is the presence of commensal animals in archaeological sites a positive correlate of sedentism? Paléorient 85–94.

Tarasov, P., Williams, J., Kaplan, J., Österle, H., Kuznetsova, T., Wagner, M., 2012. Environmental change in the temperate grasslands and steppe. In: Matthews, J.A. (Ed.), The SAGE Handbook of Environmental Change, Human Impacts and Responses. Sage, London, pp. 215–244.

Tchernov, E., 1984. Commensal animals and human sedentism in the Middle East. Animals Archaeol. 3, 91–115.

Tchernov, E., 1991. Of mice and men. Biological markers for long-term sedentism; a reply. Paléorient 153–160.

Tilley, C., 1996. An Ethnography of the Neolithic. Cambridge University Press, Cambridge.

Tome, C., Vinge, J.-D., 2003. Roe deer (Capreolus capreolus) age at death estimates: new methods and modern reference data for tooth eruption and wear, and for epiphyseal fusion. Archaeofauna 157–173.

Trolle-Lassen, T., 1986. Human exploitation of the pine marten (Martes martes L.) at the Late Mesolithic settlement of Tybrind Vig in western Funen. Striae 24, 119–124.

Vardanis, Y., Klaassen, R.H., Strandberg, R., Alerstam, T., 2011. Individuality in bird migration: routes and timing. Biol. Lett. rsbl20101180.

Vincent, J., Bideau, E., Hewison, A., Angibault, J., 1995. The influence of increasing density on body weight, kid production, home range and winter grouping in roe deer (Capreolus capreolus). J. Zool. 236, 371–382.

Von Den Driesch, A., 1976. A guide to the measurement of animal bones from archaeological sites: as developed by the Institut für Palaeoanatomie. Domestikationsforschung und Geschichte der Tiermedizin of the University of Munich. Peabody Museum Press.

Warren, G., 2014. Transformations? The Mesolithic of North-West Europe. In: Cummings, V., Jordan, P., Zvelebil, M. (Eds.), The Oxford Handbook of the Archaeology and Anthropology of Hunter-gatherers. Oxford University Press, Oxford.

Woodburn, J., 1980. Hunters and Gatherers Today and Reconstruction of the Past. Soviet and Western anthropology, pp. 95–117.

Wyncoll, G., Tangri, D., 1991. The origins of commensalism and human sedentism. Paléorient 157–159.

Zeder, M.A., 2012. The broad spectrum revolution at 40: resource diversity, intensification, and an alternative to optimal foraging explanations. J. Anthropol. Archaeol. 31, 241–264.

Zeder, M.A., Lemoine, X., Payne, S., 2015. A new system for computing long-bone fusion age profiles in Sus scrofa. J. Archaeol. Sci. 55, 135–150.

Paper III

— 12 —

The Use of Aquatic Resources by Early Mesolithic Foragers in Southern Scandinavia

Adam Boethius

A long tradition in research on prehistoric southern Scandinavia recognizes full use of aquatic resources in the Late Mesolithic Ertebølle Culture (5500–4000 cal BC): coastal sites are frequently found containing well-preserved fish bones, and isotope values from human collagen indicate a high dietary intake of marine resources. However, recent finds and new methodologies suggest that the view of a terrestrially focused diet in the Early Mesolithic period (9500–6800 cal BC) can be reinterpreted, and the use of freshwater resources is found to be more important than previously known. Aquatic resources can therefore be seen to be a major source of sustenance for foraging societies in Scandinavia much earlier than has been realized previously. At Norje Sunnansund, an Early Mesolithic site located in Blekinge, south-eastern Sweden, large amounts of fish bones have been found, and these have been used to estimate the amount of fish being caught at the site, by analyzing different rates of taphonomic loss. The results from the excavated part of the settlement suggest that at least 48 tonnes of fish were caught. The large amount of caught fish and the evidence of the means of preparing and storing them provides the earliest example of a large-scale fishing society, and the knowledge required to catch and prepare this volume of fish has further implications at a more structural societal level. A structured society is a prerequisite for the development of sedentism and enables large groups of people to gather during an extended time period. Conservative dietary estimates from the recovered fish bone material suggest that enough fish was caught to sustain 100 adults living solely on fish for over three years.

Introduction

The importance of aquatic resources has received little recognition in archaeological research regarding prehistoric foraging societies. In Scandinavian archaeology, fish are indicated as being part of the human diet, and from the Late Mesolithic period are often mentioned as a major source of sustenance. However, even if the importance of aquatic resources is recognized in the Late Mesolithic, few studies have shown *how* important it was. The lack of such studies is the result of many different factors; ultimately, however, it rests with the archaeological finds from the period, within which fishing is difficult to trace. Most Mesolithic finds consist of stone tools and stone debris, and it is hard to find evidence of fishing activities, because the material traditionally used to create fish traps and fish-hooks is organic. Some bone hooks and wooden fish traps have been preserved at sites from the Mesolithic period in southern Scandinavia (Hadevik *et al.* 2008; Karsten *et al.* 2003; Nilsson 2012; Pedersen 1995), but they are uncommon, compared with the number of archaeological sites with no organic preservation. Furthermore, fish have weaker bone attachments, softer flesh, and lighter and more fragile bones than mammals (Wheeler and Jones 1989), because buoyancy in water does not require the stable skeleton of a terrestrial mammal (Kullander *et al.* 2012; Moyle and Cech 2004). For this reason, the tools used for gutting, defleshing, and filleting fish can have a longer life than tools used on mammals, leading to fewer of this type of artefact being made. In addition, it is difficult to say for certain how stone tools were used, even if wear analysis is carried out on the flint material. It may be that a well-known category of stone tools was used solely for handling fish but without leaving any evidence of this activity, making it invisible as an indicator of fishing.

Fish bones are also more fragile than mammal bones, more susceptible to degenerative forces, and will perish faster than mammal bones (Wheeler and Jones 1989). Fish bones are also less able to withstand external forces, such as gnawing and digestion, compared with mammal bones (Butler and Schroeder 1998; Jones 1986; Nicholson 1993), and if the waste surface where fish remains were discarded is reused or mechanically manipulated (trampled), the fish bones tend to be crushed into unrecognizable fragments (Jones 1999; Wheeler and Jones 1989). In addition, fish bones are generally small in size and can only be found with the use of fine-meshed sieves (Enghoff 2011; Wheeler and Jones 1989). As fish bones are often found in areas that are not easily sieved, such as clayey, organic waterlogged soils (Wheeler and Jones 1989), a fish diet can be hard to trace. Overall, fish remains usually only make up a small part of the total bulk of preserved bone found on Early and Middle Mesolithic sites, and this gives the impression of a terrestrial-dominated diet. This bias has arisen because of the many problems related to finding and analyzing fish remains, resulting in fish receiving insufficient attention as a dietary source.

The problems of finding, excavating, and analyzing fish bone material from Mesolithic sites have led to problems when trying to interpret the importance of aquatic resources. Because excavators in the early twentieth century did not use fine-meshed sieves, few fish bones were found (Wheeler and Jones 1989, 76). The evidence from old excavations is therefore only partial (Morales *et al.* 2001, 47), making it less than useful when trying to determine the level of sustenance gained from aquatic resources. However, as archaeology has developed as a science, archaeologists have become increasingly aware of how an excavation should be conducted, what to look for, and how to look for it. This has resulted in more fish bones being found, and, even if the higher costs associated with the collection and analysis of archaeological fish remains often prevent a full-scale investigation of the importance of aquatic resources and their level of impact on human diet, there has been much progress in this field of research.

In addition to problems with assessing the importance of fish in the early Scandinavian human diet, there are other factors influencing this field of research. One is the complex relationship between transgressions and regressions since the ice melted after the last ice age (Björck 1995). When the first people arrived on the newly vacated land, large masses of water were still bound up in ice further north, and the melting of this water, along with the land rise, resulted in shifts of the coastline. This has resulted in predominantly inland sites from the

Late Palaeolithic and Early Mesolithic periods being found in southern Scandinavia, because what was once the coast is now submerged and inaccessible by means of the usual archaeological research methods (Andersen 1995). Settlements with preserved organic remains that were close to major bodies of water are therefore largely unaccounted for, and, apart from the sites of Huseby Klev (Boethius 2018) and Balltorp (Jonsson 1996, 2014), sites dating from the Early Mesolithic period are located inland, with aquatic resources available only from streams, rivers, and lakes. This compromises the comparison between Early and Late Mesolithic sites (Blankholm 2008; Brinch Petersen and Meiklejohn 2007) and, in combination with the factors explored above, has led many archaeologists to the conclusion that Early Mesolithic people were mainly nomadic big-game hunters (Jochim 2011).

This interpretation stands in contradiction to what is known from ethnographic accounts of people living as foragers. When studying foraging groups from the last two centuries on a global scale, a distinctive pattern emerges regarding their foraging strategies. The essence of this pattern is that in foraging societies the proportion of sustenance gained from hunting and fishing increases away from the equator, and the proportion of sustenance gained from gathering increases towards the equator (Cordain *et al.* 2000; Marlowe 2005). The further away from the equator you travel, the more fish-dependent the ethnographic foraging groups become (Figure 12.1), which provides some hint of the importance of aquatic resources in Mesolithic Scandinavia.

In this paper the archaeological evidence for the use of aquatic resources during the Early Mesolithic will be examined, with an emphasis on osteological methods. The insights gained from a case study of the site of Sunnansund in south-eastern Sweden will be extrapolated to contemporary sites and used to highlight the need for a profound knowledge of taphonomy and the many sources of error at play when working with aquatic remains in general and freshwater remains in particular. The volume of fish caught at Sunnansund and the way people stored the catch shows that the knowledge of how to catch substantial amounts of fish and preserve it for later use existed in the Early Mesolithic period. This has implications for how we perceive Early Mesolithic societies and emphasizes the need to answer questions regarding how many people freshwater fishing could have sustained, and how aquatic resources can be connected with population increase and a sedentary lifestyle in the Early Mesolithic.

Material

The results of this study are based mainly on the bone assemblage collected during the excavation of the archaeological site of Norje Sunnansund, situated outside Sölvesborg in Blekinge, south-eastern Sweden (Figure 12.2), dated to about 7600–6600 cal BC (Kjällquist *et al.* 2016). All of the mammal and bird bones from the site have been analysed, resulting in 1,909 identified mammal bones weighing 7,553 g, and 105 identified bird bones weighing 95 g. Altogether, 4,617 g of fish bones were excavated, and by December 2015 (when the calculations for this paper were made) 13% (595 g) of these fish bones had been analysed, resulting in 16,020 identified fish bones. This study focuses on the oldest phase of the settlement, which consists of one cultural layer and one major feature with post holes and stake holes connected to it. This phase has been radiocarbon dated to about 7600–6900 cal BC, although the period of actual occupation was shorter; this anomaly is because of the poor preservation of carbon in the collagen

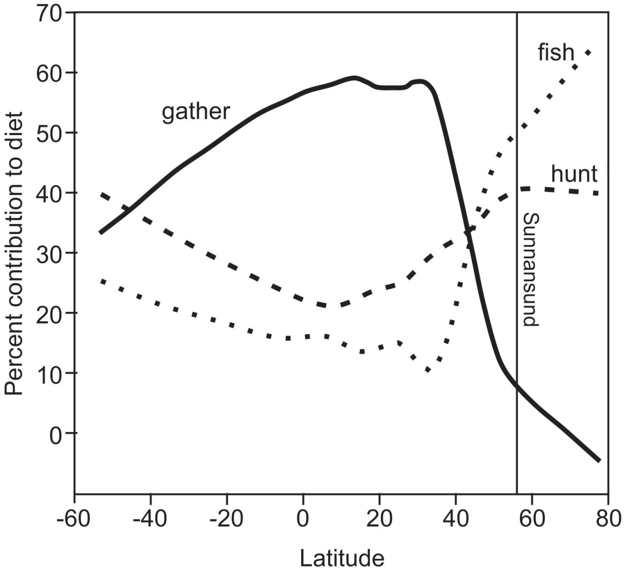

Figure 12.1 The proportion of sustenance from different types of resources at different latitudes among foraging peoples (Marlowe 2005, fig. 3). The vertical line indicates the latitude of the Sunnansund site, south-eastern Sweden. Figure used with the consent of Frank Marlowe.

of the bones and a calibration plateau between 7500 and 7100 cal BC, which has contributed to larger dating spans. The main material used in this study was the fish bones, which have been used to estimate the entire collected mass of fish belonging to the oldest phase. The oldest cultural layer corresponding to this phase contained 3,823 g of fish bones, of which 6.7%, or 250 g, were analysed, resulting in 5,102 identified specimens. The material from half of the feature has been used in this study (see the "Methods" section), consisting of 9,924 identified fish bones weighing 296 g.

The archaeological site of Norje Sunnansund

The Norje Sunnansund site, excavated in the summer of 2011, because of its unique finds, has the potential to question and/or change the current big-game-hunter paradigm of the Early Mesolithic in southern Scandinavia.

The site was located on the shore of the freshwater Lake Vesan, next to a 2 km long outlet to the slightly brackish Baltic Basin (Figure 12.2). The surrounding forest was dominated by hazel (*Corylus avellana)* and pine trees (*Pinus sylvestris*), and on the other side of Lake Vesan the elongated low mountain ridge Ryssberget stretched for about 20 km. This made the site an ecotone settlement, located at the boundary of at least two different biotopes. It was therefore an ideal habitat for many different plant and animal species to exist within a relatively small area, which is also seen in the high species diversity found on the site.

During the archaeological excavation three main layers and one main feature could be

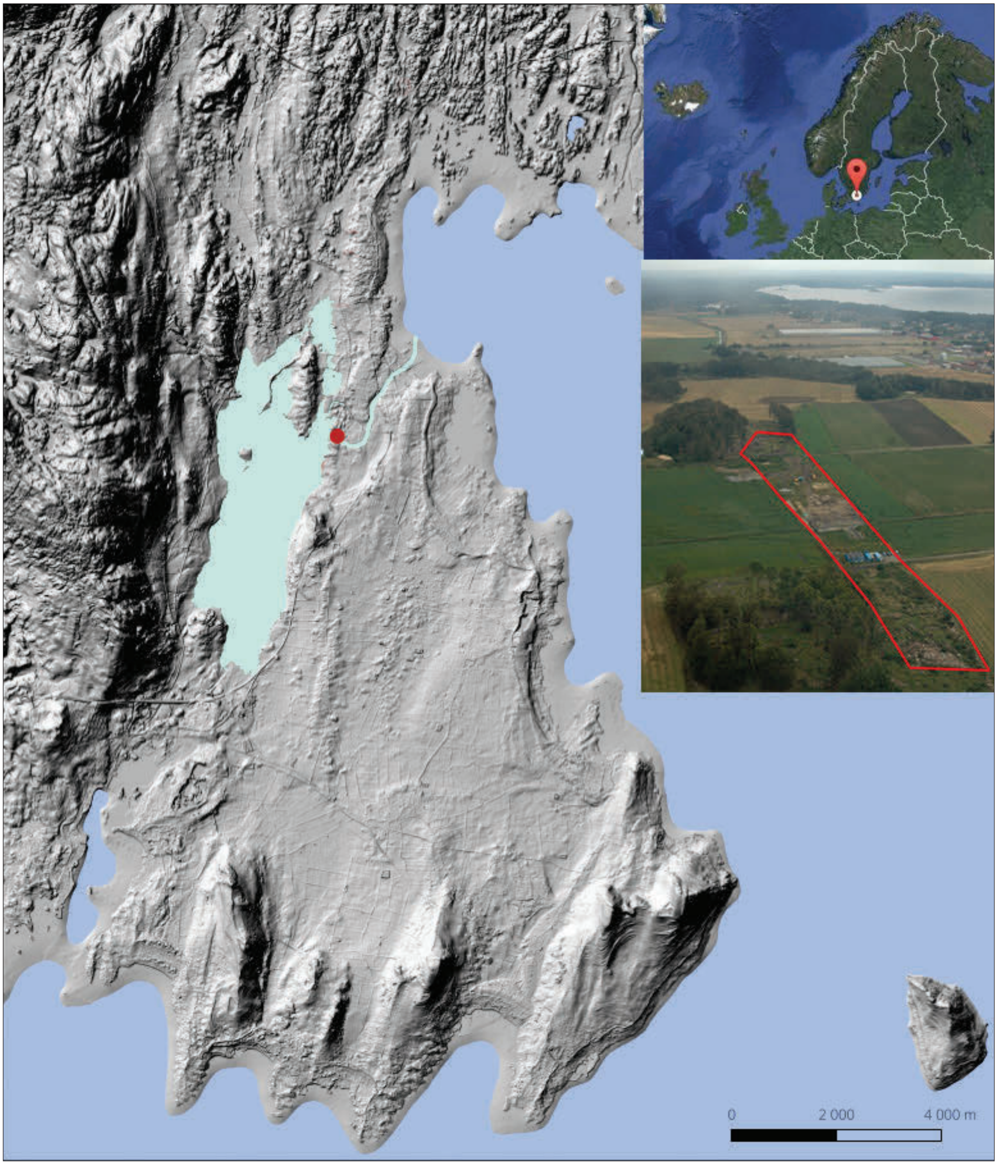

Figure 12.2 Map of the area surrounding Norje Sunnansund (red dot) c. 7200 BC. The map is based on a terrain model with 5 m resolution and on LIDAR data, with topographic information from Swedish Land Survey road maps (© Lantmäteriet i2012/892), Swedish Geological Survey, and a marine geological map from Iowtopo2 (Seifert *et al.* 2001). Map: Nils-Olof Svensson, Kristianstad UniversityThe pictures on the right display the location of the site and an aerial photo of the excavation. Satellite photo: Google Earth; photo: Blekinge Museum.

detected. The oldest layer was a dark, clayey, organic layer with good preservation, which, in turn, was covered by a sandy layer with less potential for preserving the organic archaeological material. The third layer was a waste layer, which had been dumped into the shallow waters next to land and contained elements from both of the terrestrial layers. The main feature was a shallow gutter-shaped pit, filled mainly with fish bones. Finds in and around the pit, in combination with the hermeneutic use of ethnographic analogies, indicate that it was used as a pit for fermenting quantities of fish as a means of conserving it for later use (Boethius 2016b).

This study focuses on the oldest layer and the contemporary fish fermentation pit, which, in terms of seasonal occupation, have been interpreted as covering the whole year, with intensified use during the winter season (Boethius 2017). The site is therefore the first identified winter season/year-round settlement from southern Scandinavia. The seasonality indications are, among others, based on the presence of a ringed seal foetus and young seals, a roe deer foetus, only fully grown small fur game species, and archaeobotanical evidence of wild cherry *(Prunus avium)*, bird cherry *(Prunus padus),* hawthorn *(Crataegus),* hazel catkins *(Corylus avellana)*, and sloe (*Prunus spinosa*) (Kjällquist *et al.* 2016; Kjällquist, forthcoming). Furthermore, indications of a fermentation pit and mass catches of fish imply a late-autumn and/or early-spring catch season, as cool temperatures would be needed to ferment the fish safely in the absence of salt (Boethius 2016b).

Methods

The arguments presented in this paper are based mainly on osteological analyses with the help of archaeological methods. The osteological analysis is presented in detail in the site report (Boethius 2016a). The osteological analyses of the fish bones were made with the aid of the reference collections from Riksantikvarieämbetet UV-syd, the Zoological Museum in Copenhagen, Denmark, and the Archaeological Department at Lund University, Sweden.

All bone fragments were identified to species level where possible and to family when a higher degree of identification was impossible. The cyprinids (carp family), however, because of the difficulties in identifying individual species from many of the bones, were only identified to species for the pharyngeal and basioccipital bones. The other cyprinid elements were identified to family (Cyprinidae). However, since the majority of identifiable cyprinid bones belong to roach, the size and weight estimates of cyprinids are based on roach bone calculations. Measurements on the fish bones were done according to Morales and Rosenlund (1979), if not stated otherwise, and the following size estimates were derived from these measurements. The size estimates of roach were based on a regression formula using the largest width measurement of the posterior articulation of the first vertebra, according to Enghoff (1987). For perch and pike, the size estimates were based on a regression formula from the anterior height measurement of the dentale, with additional size estimates for pike based on the smallest medio-lateral middle breadth on the parasphenoidale according to Enghoff (1994). For eel, the size estimates were based on the corpus length of the precaudal vertebra types 3, 4, 5, and 6, and the cleitrum anterior-posterior height of the midshaft, according to Thieren *et al.* (2012). Weight estimates for these four fish species were based on the average calculated total length (TL) of each species and the equation $W=aTL^b$. The weight of roach and eel was calculated according to Koutrakis and Tsikliras (2003), and that of perch according to Kleanthidis *et al.* (1999), using data from Neophytou (1993). The weight of pike was estimated using the equation $W=10^{((a \log TL)-b)}$ according to Willis (1989). In both equations W is the estimated weight, TL is the calculated total length, and a and b are constants varying between the different fish species. The weights of the less frequently occurring fish species were based on size and weight comparisons with modern fish bones from the comparative collections. The total calculated amount of fish caught at Sunnansund and the implication for human diet was therefore based on the approximate weight corresponding to the average size of each fish species.

The analysed fish bones from Sunnansund used in this study were all retrieved using a 2.5 mm sieve. However, because there are large size variations between and within fish species, smaller fish bones will have been missed. It was therefore important to examine how great these losses were. This was done by sifting 1 dl control samples of soil through different mesh sizes (2.5, 1, and 0.4 mm) and checking the amount of identifiable fish bone in each mesh (Boethius 2016a). These results were used to recalculate the amount of fish bone that would have been found if smaller screen sizes had been used across the entire excavation surface, using the amount of identifiable fish bone with each mesh size to create a multiplication factor based on the abundance of the different species found in the sieves (Table 12.2). This, in turn, was extrapolated to a minimum number of individuals (MNI) found for each fish species and their calculated average weight (Table 12.1). Fish found in the smaller meshes were smaller, and the estimated weights of these fish were approximated to 50 g per individual. In the cultural layer MNI was based on the following elements: eel–*cleitrum*, cyprinids–*pharyngea*, pike–*vertebrae 1*, burbot–*vertebrae*, perch–*vertebrae 2*, pike perch–*vertebrae*, ruffe–*hyomandibulare*, whitefish–*vertebrae*, trout–*vertebrae*, salmonids–*vertebrae.* In the gutter the following elements were used: eel–*vertebrae*, cyprinids–*pharyngea*, pike–right *quadratum*, burbot–*vertebrae 1*, smelt–*vertebrae*, ruffe–*vertebrae*, perch–*vertebrae 1*, pike perch–*vertebrae*, whitefish–*vertebrae*, salmonids–*vertebrae*. The calculations are derived from estimates based on using a 2.5 mm sieve. Since 4 mm sieves were used on 55% of the excavated cultural layer, this means that the weight of the excavated fish is restrictively calculated, as the number of retrieved fish bones would have been higher if the entire site had been excavated using a 2.5 mm mesh, implying larger amounts of caught fish. Similarly, the analysed fish bones from the stake and post holes that surrounded the fermentation pit feature have been disregarded in this study and are not included in the estimates, due to difficulties with aggregation when tallying MNI in different contemporaneous contexts. The NISP and MNI within each stake and post hole can be found in Boethius (2016b); however, as cumulative MNI has not been tallied, their contribution to the estimates is omitted.

The feature was excavated differently from the other parts of the site, where the cleanup area (transitional area between the cultural layer and feature cut) and half of the fill of the feature was excavated using a 2.5 mm sieve and the other half using a 5 mm sieve. Since only fish retrieved from 2.5 mm sieves have been used in this study, and due to the major loss in fish bone recovery when doubling mesh size (a 94 % extra loss of fish bones when applying a 5 mm mesh instead of 2.5 mm; Boethius 2016b), calculations have only been based on the parts sieved with 2.5 mm, and the results from this (western) half have been extrapolated to the other half as if the entire feature had been homogeneously sieved.

This paper aims to provide estimates based on extrapolations and assumptions of homogeneous bone dispersal over unexcavated and unanalysed parts of the site. Therefore, given the following description of the logical chain of events, the subsequent estimates should not be considered to give the "true" amount of caught fish, but rather a logically derived calculation of the estimated quantity. Therefore, the main purpose of this paper is to offer rough approximations intended to quantify the amount of caught fish, given different taphonomic survival rate scenarios. These estimates are intended to show the massive underrepresentation of fish bones in Mesolithic archaeological contexts and serve to illustrate a new dimension of available interpretations, when the importance of aquatic resources is fully considered and explored.

Results

A prerequisite for a sound taphonomic evaluation of an archaeological site is an understanding of the sequence of events that have occurred between deposition and recovery. The site of Sunnansund was covered with a thick layer of mud that preserved the site from shortly after its occupation until today. This led to good preservation that, in combination with careful excavation, has meant the site has yielded a wide array of hunted mammals, birds, and fish, with more species present than on contemporaneous sites (Figure 12.3).

Although more species were found at Sunnansund than on any other contemporaneous site, what truly sets it apart is the large amount of fish bone found there. The fish bone recovered at Sunnansund exceeds more than 100 times what has previously been found on any other southern Scandinavian Early or Middle Mesolithic site. Even though only around 13% of the recovered fish bones from Sunnansund have been analysed so far, the numbers greatly surpass the identified amount of fish bone from any contemporaneous site (Figure 12.4).

The difference in quantity does not necessarily indicate a more fish-oriented diet at Sunnansund, because of the taphonomic losses and variation in preservation and excavation techniques between the different sites. At no other site have fine-mesh sieves (<3 mm) been applied to clayey soil, where the best potential of finding preserved fish bone exist, on more than individual samples. Even though water sieves have been applied on some of the excavations (Huseby Klev, Tågerup, and Balltorp), the mesh sizes were larger than at Sunnansund (4–10 mm, compared with the 2.5 mm mesh size applied to the contexts at Sunnansund in this study), and only small samples were sieved with sieves having a finer mesh. Due to the massive decrease in fish bone recovery when applying larger sieves (Boethius 2016b), the end results would have been different, if finer sieves had been used on these sites. On other sites (Ringsjöholm) fine-mesh sieves have been applied in some areas of the excavation, which have generated a quantity of fish and bird bone. However, the bone material has never been comprehensively analysed, and it is impossible to obtain any estimates regarding the quantity and specifics of the fish. Even more, on other sites (Hög) the preservation has probably been a limiting factor, and even though water sieves were applied (unknown mesh size and frequency), the low number of fragments from these sites indicates that much has been lost. The fact that all the rest of the sites have not been water-sieved at all, or only on unspecified small samples, indicates that the trends illustrated above reflect a mixture of taphonomic losses. Therefore, what has previously been known to be true regarding Early and Middle Mesolithic subsistence strategies should be regarded as heavily biased. Because all sites are partial, the large amount

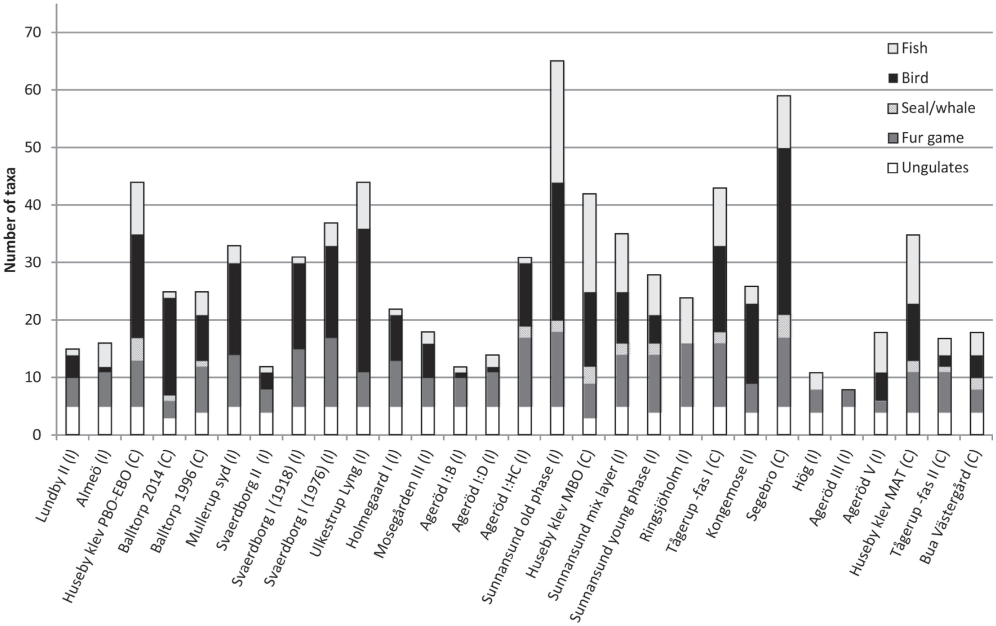

Figure 12.3 Number of species from different animal categories (NTAXA) on Early and Middle Mesolithic southern Scandinavian sites, displayed in chronological order. The number of identified specimens (NISP) on which NTAXA is based is displayed in Figure 12.4. (I) indicates inland freshwater environment; (C) indicates coastal marine environment. Data from: Lundby II (Rosenlund 1980), Almeö, (Arnesson-Westerdah, 1984), Huseby Klev (Boethius 2018), Balltorp (Jonsson 1996, 2014), Mullerup (Leduc 2012; Sarauw 1903), Sværdborg (Aaris-Sørensen 1976; Johansen 1919; Rosenlund 1971), Ulkestrup Lyng (Noe-Nygaard 1995), Holmegaard I (Broholm *et al.* 1924), Mosegården III (Møhl 1984), Ageröd I:B, I:D,I:HC, III, V (Larsson 1978; Lepiksaar 1978, 1983a; Magnell 2006, manuscript), Sunnansund (Boethius, in print), Ringsjöholm (no data for bird taxa) (Jansson *et al.* 1998; Magnell 2006, manuscript), Tågerup (Eriksson and Magnell 2001), Kongemose (Noe-Nygaard 1995), Segebro (Lepiksaar 1982), Hög (Iregren and Lepiksaar 1993), Bua Västergård (Lepiksaar 1983b).

of fish bone from Sunnansund can be used as a basis for estimating dependence on aquatic sustenance; these results can be used to further our understanding of Early Mesolithic subsistence strategies in general. Especially since most Early Mesolithic sites are inland summer occupations, while Sunnansund is a coastal settlement with year-round presence, the majority of seasonality indicators falling in the period from winter to spring.

Estimating Fish Abundance

The average size and weight of the most commonly caught fish had to be established, in order to provide a fish quantity approximation from the Sunnansund fish bone material (Table 12.1). By extrapolating the average estimated fish weight from each individual species to the entire excavated bone assemblage it was possible to gain an estimate of the amount of meat each species contributed (Table 12.2).

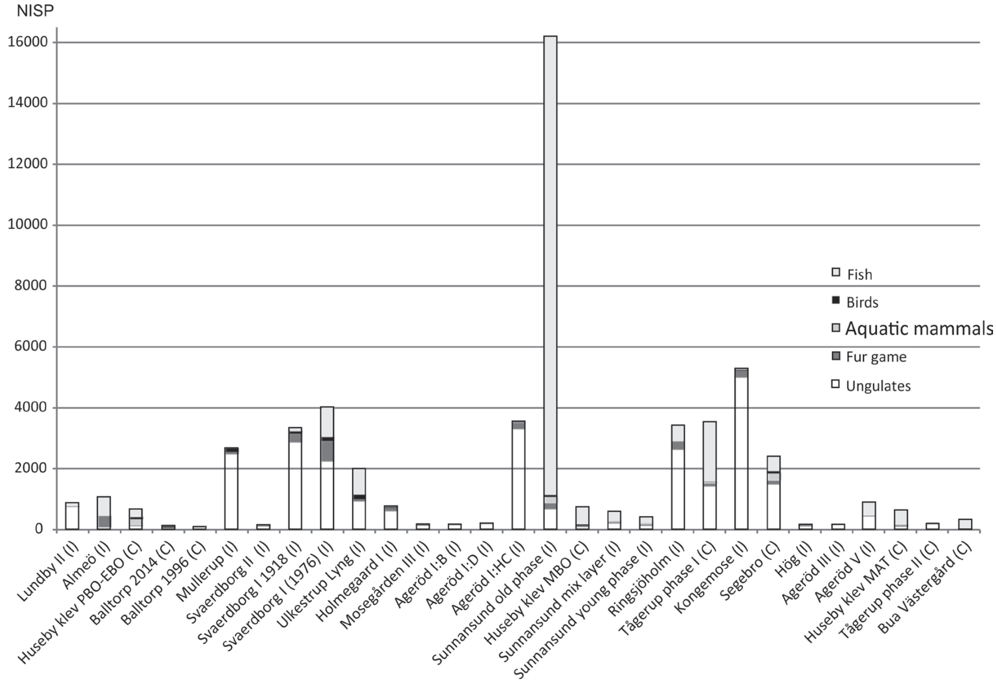

Figure 12.4 NISP for the main animal categories from Early and Middle Mesolithic southern Scandinavian sites. Note that the fish bone material from Sunnansund, Huseby Klev, and Ringsjöholm is partially analysed and that the fish remains from Mullerup and Hög have not been specified. In the case of the Sunnansund early phase only 15% of the fish bones have been studied. (I) indicates inland freshwater environment; (C) indicates coastal marine environment.

There are only freshwater species present in the fish bone material from Sunnansund, because Lake Vesan and the Baltic Basin were freshwater and slightly brackish, respectively, during the period of site occupation. Roach clearly dominates the bone material and would have been an important reason for humans staying at the site. The roach from Sunnansund are large, and the sizes correspond to how big a roach can grow in 5–10 years. Roach fishing at Sunnansund was therefore initially interpreted as being carried out with a 5–10 year interval between each fishing activity, and with large quantities of roach extracted during each visit, the lake then being left for a number of years to recover. The lack of peaks in size at Sunnansund is also a difference from other Mesolithic sites (Boethius 2016a); such peaks have been interpreted as corresponding to high-intensity fishing on an annual but short fishing season (Enghoff 1995), and the lack of them at Sunnansund implies the site was visited less frequently than once a year. However, the fishing activities from other sites were mainly carried out during the summer, and all indications from Sunnansund suggest that this site was occupied during all seasons; therefore, the data cannot be interpreted on the same basis. Considering the size of the roach and their massive numbers, it is likely that they were caught during a favourable time of year. Today, brackish-living

Table 12.1 Average size and weight estimations for each fish species found at Sunnansund. The weight of the less frequent fish species was estimated by comparing the size of the bones with modern reference specimens of known weight. TL = total length, W = total weight, x = unique measure for each bone element (see methods).

Species	**Element**	**Size equation (x=measurement)**	**n**	**Average size TL (cm)**	**Size-weight equation**	**Average weight (kg)**
Pike (*Esox lucius*)	Dentale	$TL=119.3059*x^{0.9048}$	17	53	$W=10^{((3.059*\log TL)-5.369)}$	0.93
	Parasphenoidale	$TL=181.6086*x^{0.8921}$	4			
Roach (*Rutilus rutilus*)	Vertebrae 1	$TL=76.4364*x^{0.8331}$	134	27	$W=0.0053\mathrm{TL}^{3.35}$	0.32
Perch (*Perca fluviatilis*)	Dentale	$TL=95.6287*x^{0.8530}$	5	30	$W=0.0229\mathrm{TL}^{2.83}$	0.35
Eel (*Anguila anguila*)	Cleitrum	$TL=278.6*x^{0.7875}$	4	53	$W=0.0003TL^{3.47}$	0.30
	Precaudal vert type 3	$TL=139.46*x^{0.9478}$	1			
	Precaudal vert type 4	$TL=134.2*x^{0.9404}$	3			
	Precaudal vert type 5	$TL=122.94*x^{0.9616}$	7			
	Precaudal vert type 6	$TL=120.71*x^{0.975}$	4			
Whitefish (*Coregonus*)	Comparative size					0.5
Burbot (*Lota lota*)	Comparative size					0.8
Smelt (*Osmerus eperlanus*)	Comparative size					0.05
Ruffe (*Gymnocephalus cernua*)	Comparative size					0.05
Pike perch (*Sander lucioperca*)	Comparative size					0.5
Salmonids (*Salmonidae*)	Comparative size					0.8
Trout (*Salmo trutta*)	Comparative size					0.8

roach migrate in large numbers up streams and rivers to spawn in the shallow freshwater conditions of inland lakes and streams (Kullander *et al.* 2012). Roach normally spawn in the spring, but they also have a tendency to fake spawn in the late autumn–early winter (Curry-Lindahl 1969). At the time the Sunnansund settlement was occupied, the Baltic Basin had recently opened up to the Kattegat through the Danish straits in the south (Gustafsson and Westman 2002). This let brackish water intrude into the Baltic, with the first evidence of saline water reaching the coast of Blekinge around 7800–7400 cal BC (Berglund *et al.* 2005). The second phase of the Littorina Sea, 7400–6500 cal BC, coincides with the Sunnansund settlement and is characterized by rich organic sediments with mainly freshwater diatoms, but with a low number of brackish taxa, indicating low marine input (Berglund 1964; Berglund *et al.* 2005). Although this stage is characterized by very low salinity (Berglund *et al.* 2005, fig. 12), it would have been enough to make the southernmost parts of the Baltic slightly brackish. A large body of slightly brackish water connected to a freshwater lake by a stream therefore ensures perfect conditions for catching roach. The fermentation pit further suggests that the fish were caught in the autumn, during fake spawning, and fermented during the winter, when it was cold enough to ferment the fish safely. However,

Table 12. 2 Mass of excavated fish, when using weight estimates (Table 12.1) and extrapolating the identified MNI for each fish species to the rest of the unanalyzed fish bone assemblage and correcting for partial fish bone retrieval (see methods). *Smelt and ruffe MNI was set in proportion to the amount of small cyprinids found in macro-samples.

Context during old phase	**Cultural layer**		**Fermentation gutter**		**Based on 100% (both contexts)**	**Macro sample correction**	**Calculation after macro sieve correction**		**Average calculated individual weight**		**Total mass from each species**
Parts analyzed and quantified	**6.70%**		**W-half, cleanup area**								
Quantification unit	**NISP**	**MNI**	**NISP**	**MNI**	**Calculate MNI**	**Correction factor**	**MNI**		**kg**		**kg**
							Macro	Total	Original	Macro	
Eel (*Anguilla anguilla*)	58	2	77	2	34			34	0.30		10
Cyprinids (*Cyprinidae*)	3644	91	7891	213	1748	2.8	3146	4894	0.32	0.05	717
Pike (*Esox lucius*)	416	10	519	10	167			167	0.93		155
Burbot (*Lota lota*)	25	1	25	1	21			21	0.8		17
Smelt (*Osmerus eperlanus*)	0	0	10	2	*	0.0629*	300	308		0.05	15
Ruffe (*Gymnocephalus cernua*)	1	1	47	2	*	0.0681*	325	333		0.05	17
Perch (*Perca fluviatilis*)	921	35	1301	35	585	1.83	486	1071	0.35	0.05	229
Pike perch (*Sander lucioperca*)	20	1	5	1	17			17	0.5		8,5
Whitefish (*Coregonus*)	11	1	19	1	17			17	0.5		8,5
Trout (*Salmo trutta*)	1	1			15			15	0.8		12
Salmonids (*Salmonidae*)	5	1	5	2	19			19	0.8		15
Total	5102	144	9924	270	2623			6896			1204

it is also likely that the spawning period in the spring was used as a means of easy access to large numbers of fish. Roach living in a nutritious environment can reach sizes of up to 25 cm in five years, and as roach are sexually mature at around 3–5 years of age, and it is only sexually mature individuals that are involved in spawning activities (Curry-Lindahl 1969; Kullander *et al.* 2012), it is likely that these large sizes indicate roach were being caught when gathered for spawning activities, both fake and true spawning. Because the roach would have migrated from a large brackish water body to spawn, it is also likely that the humans did not have the capacity to over-exploit the fish population, even if the catches were made on a yearly basis.

In order to estimate the total mass of fish caught, calculations had to be made based on what was preserved, excavated, and analysed on the site (Table 12.2). These calculations show the amount of meat each fish species contributed, with corrections made to account for the partial analysis of the excavated bone material. Corrections were also made to account for what would have been found if the entire site had been excavated using 0.4 mm sieves (see "Methods" section).

Discussion

Stable isotopes—further bias in detecting freshwater fish consumption

It has been hypothesized since the mid nineteenth century, when the first large shell heaps were found in Denmark and recognized to be of anthropogenic origin, that during the Late Mesolithic period marine aquatic resources were a major contributor to human sustenance. This was further proven many years later, when Henrik Tauber showed that the $\delta^{13}C$ isotope values in Late Mesolithic human collagen were derived from a marine diet (Tauber 1981), and has been demonstrated many times since (Fischer *et al.* 2007; Richards and Price 2003). However, there are many problems with studying aquatic sustenance in the Early Mesolithic period, with few, if any, possibilities of obtaining a deep and profound knowledge of how important these resources were, because of the extensive taphonomic losses involved in the preservation and recovery of ancient fish bones. Furthermore, even though archaeologists have been able to extract information regarding human diet from stable isotopes for more than 40 years, starting with the use of $\delta^{13}C$ in the 1970s and the use of $\delta^{15}N$ in the 1980s (Ambrose and DeNiro 1986; DeNiro and Epstein 1981; Van Der Merwe and Vogel 1978; Vogel and Van der Merwe 1977), the accuracy of some of these methods has been questioned, and there are problems when dealing with time periods close to the ice age, when "ancient water" that had been bound in the ice for thousands of years was released into the oceans, lakes, rivers, and streams. When this water was released, it disturbed the balance of carbon in the water, affecting in particular the freshwater lakes, for hundreds of years (Fischer *et al.* 2007). There are also further problems when dealing with $\delta^{13}C$ values from freshwater lakes because they have a varied $\delta^{13}C$ composition in their phytoplankton, depending on the trophic state of the lake (Grey *et al.* 2000), which, in turn, affects the fish eating the plankton. Each freshwater lake has been shown to have a more or less unique chemical composition, and as a result the $\delta^{13}C$ value varies between different lakes (Milner *et al.* 2004). The $\delta^{13}C$ values have even been observed to vary within a lake (Hecky and Hesslein 1995), thereby giving different fish species different $\delta^{13}C$ values, depending on where in the lake and at what water depth they lived (Katzenberg and Weber 1999; Katzenberg *et al.* 2009). The problems with the $\delta^{13}C$ values make it hard to trace human diet if a large freshwater fish component is suspected, because the reference values are indeterminable if local faunal isotope samples from each archaeological site are unavailable to compare with the human bone isotope values. $\delta^{15}N$ values for freshwater fish have also been hard to interpret because of a somewhat shorter freshwater food chain, compared with a marine environment (Cohen and Fenchel 1994, 57), which gives lower human $\delta^{15}N$ values when subsistence is based on freshwater instead of marine fish (Katzenberg 1989). There is also a diminished food chain at higher latitudes, because of the smaller number of available species in colder water (Wheeler and Jones 1989, 30). Furthermore, many relatively large freshwater fish are herbivores or feed on small plankton and invertebrates (cyprinids), which places them low in the food chain (Fuller *et al.* 2012), with a $\delta^{15}N$ value at the same level as terrestrial omnivores. The isotopic impact on human bones from a freshwater fish diet is therefore complex and has not been investigated properly, and it has even been suggested that there is no possibility of measuring freshwater fish consumption (Hedges and Reynard 2007). This makes it hard, sometimes impossible, to determine whether components of human diet came from terrestrial mammals or freshwater, low-food-chain fish (Fischer *et al.* 2007). More recently, problems with the diet offset from prey to predator have been noted: this may be as large as 6‰, instead of the 3–3.5 ‰ offset commonly used (O'Connell *et al.* 2012). In some cases a freshwater fish diet has been identified, such as at the large cemetery of Zvejnieki, Latvia, where the isotope values of $\delta^{13}C$ and $\delta^{15}N$ correspond well with a freshwater-fish diet (Eriksson 2003), given a prey-to-predator offset of around 3‰. However, as this site is younger, and none of the humans subjected to isotope analysis correspond to the Scandinavian Early and Middle Mesolithic, and as this site is located on the opposite shore of the Baltic, it has not had a large impact on the interpretation of earlier Scandinavian settlements. Lately there have been methodological developments in the field, using compound-specific carbon isotope analysis of amino acids to distinguish between a freshwater and a terrestrial diet (Webb *et al.* 2015). Even though this method shows promising results, it has yet to be applied outside the initial study.

Quantifying the unknown

Calculations of the total amount of preserved fish bone found from the oldest phase at Sunnansund gave an estimate of 1,204 kg of caught fish (Table 12.2). The biostratonomical and diagenetic taphonomic losses, such as waste disposal, trampling, weathering, fluvial processes, and bone preservation in the soil, have a large impact on what is preserved in archaeological samples. These losses are hard to quantify, although many researchers have tried to account for them, using different types of deduction techniques based on the MNI, element frequency, and NISP (Aaris-Sørensen *et al.* 1983; Magnussen 2007; Noe-Nygaard 1995). Calculations based on these types of deductions are just one way of looking at the problem of taphonomic loss, and yield a relatively low taphonomic loss compared with other methods based on alternative interpretations of the evidence (Gautier 1984; Noddle 1977). However, even if this type of taphonomic loss is hard to calculate accurately, the estimate gives an idea of the extent of the loss. Calculations made by Danish researchers have often arrived at a taphonomic bone loss of around 75–100% when applied to terrestrial mammals (Noe-Nygaard 1995), often settling around 90% (Magnussen 2007). When applying these deductive principles to the cyprinids from Sunnansund, the taphonomic loss is larger than that for terrestrial mammals. A roach has about 1,500 bones, and with 11,535 cyprinid bones from 304 individuals, the taphonomic loss amounts to about 97.5%. As fish bones do not preserve as well as mammal bones, because of their size and frailty, greater taphonomic loss is to be expected. However, even a survival rate of 2.5% of fish bones could be considered too much, as illustrated by ethnographic accounts from 1973 in Kenya, Africa. Here, excavation and evaluation of small foraging camps with known numbers of fish caught and brought to the site indicated that only 10–20% of the bones survived, depending on the species and how they were cooked (Stewart and Gifford-Gonzalez 1994). These surveys of foraging sites were carried out within a few months after they were abandoned, which implies a much higher taphonomic loss of bones from an archaeological site abandoned for 9,000 years. It has been stated that the taphonomic loss of fish bones on archaeological sites cannot be said to be anything other than enormous (Wheeler and Jones 1989).

If a 2.5% survival rate for the fish bones is applied at Sunnansund then the original inhabitants caught almost 50 tonnes of fish, calculated from the archaeologically investigated area. Furthermore, only about 26% of the oldest layer within the archaeological excavation perimeters was investigated (211 of 800 m^2), and these perimeters only covered about 30% of what is estimated to be the original size of the settlement (Kjällquist *et al.* 2016). Therefore, only about 8% of the original settlement has been subjected to archaeological investigation. This means that the original mass of fish caught would have been a lot higher. If the uninvestigated areas of the settlement were as densely packed with fish bones as the investigated ones, and this pattern is representative of the entire original settlement surface, it means that the original mass of caught fish amounted to 609 tonnes. However, because it is not known what lies in the unexcavated parts of the site, and bearing in mind that the excavation targeted the most interesting areas within the excavation perimeters, it is better to take a more conservative approach and estimate the remaining part of the settlement as containing a third of the amount found in the excavated part. This means that the occupants caught around 235 tonnes of fish at the site. Data from ethnographic peoples in Siberia indicate that an adult living solely on a fish diet requires about 2 kg of fish per day (Eidlitz 1969); 235 tonnes of fish would therefore be enough to feed 100 people for around 3.2 years.

These calculations are based on 2.5% taphonomic loss and on a scenario where the people lived solely on fish. The presence of bones from a wide array of different land mammals, birds, and seals, accompanied by large amounts of hazelnuts and many different species of fruits and berries (Boethius 2016a; Lagerås *et al.*, forthcoming), therefore indicates more people or a longer presence on the site. The radiocarbon dates from the early phase of the site indicate a long occupation of up to 600 years. However, because there have been large problems with contaminated bones, diagenesis, and badly preserved carbon in the bone collagen, and because the site was occupied during a small radiocarbon plateau, the calibrated date spans are large. The actual period of habitation would have been more concentrated than the radiocarbon dates imply. Reasoning that the actual use of the settlement lasted for a shorter duration than the radiocarbon date range suggests, and even though it is hard to narrow down the occupation of the site and the possible number of visits based solely on the archaeological and osteological material, certain contemporary global events do provide some context for placing the site spatially and temporally.

The chronology for three Greenland ice cores show synchronous evidence that three cooling events happened during the Early Holocene, the well-known 8.2 k event (Alley and Ágústdóttir 2005), an event of shorter duration but of almost similar amplitude around 9.2–9.3 k before present, and the Preboreal Oscillation during the first centuries of the Holocene. The 9.2 k episode resulted in large amounts of freshwater flooding into the Atlantic Ocean around 7200 cal BC, temporarily lowering the effect of the Atlantic Thermohaline circulation, which led to a drastically cooler climate in the Northern Hemisphere (Fleitmann *et al.* 2008). This event is thought to have lasted for about 70 to just over 100 years, based on the $\delta^{18}O$ and accumulation signals recovered from ice core samples extracted from the Greenland Ice Sheet (Rasmussen *et al.* 2007); no values suggest that this cooling of the climate lasted for more than 150 years (Fleitmann *et al.* 2008). This places the event within the calibrated dates for Sunnansund. Further, the bones from newborn ringed seals and a bone from a ringed seal foetus have been

Table 12.3 Three different taphonomic survival rate scenarios and their implication for population and site occupation.

Estimated taphonomic survival rate	2,5%	0,025%	0,0005%
Mass of excavated fish (kg)	1204	1204	1204
Estimated original mass of caught fish (kg)	48,160	4,816,000	240,800,000
Excavated % of old layer within excavation perimeters	26%	26%	26%
Archaeological excavation perimeters covering original site	30%	30%	30%
Total mass of caught fish if unexcavated parts of the site holds the same amount of fish bones as the excavated parts (kg)	608,657	60,865,719	3,043,285,940
Total mass of caught fish if unexcavated parts holds 1/3 of the amount from the excavated parts (kg)	234,992	23,499,240	1,174,961,980
Amount of available fish if the location is visited 10 times (kg/visit)	23,499	2,349,924	117,496,198
Number of days 100 adults can live solely on fish if site visited 10 times (days)	117	11,750	587,481
Number of days 500 adults can live solely on fish if site visited 10 times (days)	23	2,350	117,496
Amount of available fish if the location is visited 40 times (kg/visit)	5875	587,481	29,374,049
Number of days 100 adults can live solely on fish if site visited 40 times (days)	29	2937	146,870
Number of days 500 adults can live solely on fish if site visited 40 times (days)	6	587	29,374
Amount of available fish if the location is visited 100 times (kg/visit)	2350	234,992	11,749,620
Number of days 100 adults can live solely on fish if site visited 100 times (days)	12	1175	58,748
Number of days 500 adults can live solely on fish if site visited 100 times (days)	2	235	11,750
Amount of available fish if the location is visited 500 times (kg/visit)	470	46,998	2,349,924
Number of days 100 adults can live solely on fish if site visited 500 times (days)	2	235	11,750
Number of days 500 adults can live solely on fish if site visited 500 times (days)	0.5	47	2,350

found (Boethius 2017). Ringed seals make their birthing lairs within the ice, and the presence of newborn cubs and a foetus indicates that there must have been ice thick enough for the ringed seals to spawn in the vicinity of the site. Looking at the ringed seal population of today, the furthest south where ringed seal spawning takes place is the Gulf of Riga. The average temperature in the Gulf of Riga is about 4°C lower during the winter than in the Blekinge area, which is sufficient for a thick enough ice sheet to form. This indicates a drastically cooler climate in a period with a climate trend of warmer winters, even if still about 1.5°C cooler than today (Davis *et al.* 2003). This brief window provides a time frame for when people were able to gather at this location. The fermentation pit also plays a role in this interpretation, as a cooler climate is essential in order to ferment fish without using salt. If this climate event is used to delimit the time the site was occupied, instead of a 600-year span we arrive at around 100 years of occupation, with the possibility of an occupation period as short as 40 years. Depending on whether the site was used every year or during other intervals, and considering different survival rates, a number of different scenarios can be suggested. If applying deductive estimates designed to illustrate the amount of fish caught at Sunnansund, three scenarios can be considered (Table 12.3). The first scenario uses a bone survival rate of 2.5%, based on bone element frequencies of roach bones from Sunnansund. The second scenario uses a bone survival rate of 0.025%, based on estimates from medieval King's Lynn, UK (Noddle 1977). The third scenario uses 0.0005%, based on the bone survival estimates from the Iron Age–Medieval fortified village of Eketorp, Sweden (Gautier 1984). Calculations for the mass of caught fish and the number of days and the number of people this amount of fish could sustain are based on the assumption that the unexcavated part of the site contains one-third of the amount of fish bone found in the excavated part and that an adult eats 2 kg of fish per day if living solely on fish. The estimates do not take any other type of diet into account, which means that the actual time of site occupation and the number of people living at the site was considerably larger than what is indicated by the fish consumption alone. The estimates are only based on adult human consumption, even though children and dogs would also have been consuming fish.

The lithic technology and raw materials found on the site indicate that Sunnansund might have functioned as a focal point where larger groups of people gathered for a period of time (Kjällquist *et al.* 2016). The number of people that could be sustained on a fish diet for a long period considering a 2.5% or less survival rate, as seen in Table 12.3, therefore provides a good indication of the importance of the aquatic freshwater resources and hints at how these resources may have been massively underestimated by archaeologists. It is also clear that the model based on estimates of bone survival from the Eketorp fortification does not correspond with any plausible assumptions regarding population density and the number of times the site was visited. This means that the actual bone survival rate probably lies somewhere between the estimates from Sunnansund and King's Lynn, which is between 2.5% and 0.025%. Depending on what you consider to be a likely scenario, this suggests that, if you use a 2.5% survival rate, 100 people could have lived solely on fish for more than three year-round visits. If you are inclined to believe in a higher taphonomic loss of fish bone, the deductive estimates suggest that if you apply a 0.025% survival rate, fish consumption supported as many as 500 people visiting the site 100 times and staying for two-thirds of the year at each visit or (if put in terms of a sedentary settlement) 100 people living at the site all year round for 337 years.

Conserving and preserving the fish

These large amounts of caught fish would have required an intricate and advanced knowledge of preserving the fish for later use, knowledge that in the European archaeological record does not become visible on a large scale until about 7,000 years later, during the Roman period (Morales *et al.* 2001, 46). Indirect evidence for the preservation and storage of both fish and other food products from various Late Palaeolithic and Mesolithic sites has been presented (Rowley-Conwy and Zvelebil 1989). However, this evidence is all based on “logical reasoning,” such as numbers of fish bones at a site or the evidence of mass capture technology, such as fish traps and nets. This reasoning is used in combination with the assumption that certain parameters are met, which suggests food storage is the most advantageous option compared with other risk-reducing factors, such as higher mobility. It is assumed that, if large catches are made, there must also be the means to prepare and store the produce; otherwise the catch would go to waste. The fish fermentation pit from Sunnansund is therefore unique in displaying the actual means of preserving these large catches (Boethius 2016b) and meeting the demands made by large groups of people gathering in one place over an extended time period. The fermentation process itself could be done without much additional work, making it a useful practice when preparing and storing large quantities of food for large groups of people. The location of Sunnansund also fits perfectly within the parameters for storing food, as set out by Rowley-Conwy and Zvelebil (1989), which include the possibility of utilizing more than one source of sustenance at the same campsite, combined with proximity to water. In the case of Sunnansund these criteria are met on land by the different game and plant species that could be exploited from the diverse biotopes present on the low mountain ridge of Ryssberget, the surrounding pine and hazel forest, the beach vegetation zones, and in the waters in proximity to the Baltic Basin, in direct contact with Lake Vesan and in the river outlet between the two bodies of water.

Conclusions

The term “hunter and gatherer” has been used throughout the last century in archaeological research on the Early Mesolithic in southern Scandinavia. This term has probably not been used consciously to exclude an interpretation of human populations as fishing societies, but it sums up the way these societies have been thought of and labelled by researchers. Recent finds, in combination with the recognition of the incomplete nature of early excavations, should change this opinion. If humans started to rely on aquatic resources earlier than previously suspected, it implies a bias in the interpretations regarding subsistence and societal structures. Aquatic exploitation has previously been seen as a major contributor to Late Mesolithic Scandinavian diet (Fischer *et al.* 2007), and the commonly occurring coastal sites often display evidence of year-round habitation, making a strong case for a sedentary lifestyle (Richards and Price 2003). However, if aquatic resources were a major source of sustenance much earlier on and throughout the Scandinavian Mesolithic, this has significant implications for how these societies are now interpreted. Taking the Sunnansund location as an example, the huge amounts of fish caught at this site clearly predate all known large-scale fisheries in Europe, and the fact that the people knew how to catch and prepare these amounts of fish indicates how important fishing was for subsistence. The knowledge and means to store such vast amounts of food, and the tendency to consume the majority of large stores of produce while sedentary, indicate that the human populations planned for and repeatedly sought a (semi-) sedentary lifestyle, where they could gather in larger groups for an extended period. A long stay at the same location is also a highly plausible interpretation when considering the fermentation pit, as large storage reserves and frequent mobility are incompatible activities. The cost in energy of transporting large volumes of stored reserves to different base camps would, in most circumstances, be considered too great (Rowley-Conwy and Zvelebil 1989, 47). The use of storage, as seen in the fermentation pit, is also a good indication that major storage reserves were set up in locations at the boundary between different biotopes. Stores of one food type can be used to reduce the risk of starvation by serving as a backup for the extraction of other food sources from the same base camp. Large stores of food are more likely to be utilized in locations at biotope boundaries, whereas the risk-reducing strategy for locations where only one food source is available is to constantly move to reduce the risk of failure (Rowley-Conwy and Zvelebil 1989, 48). It therefore becomes important to be able to trace storage behaviours in diverse-biotope settlements, as these provide a clear indication of a more sedentary approach to subsistence strategies.

The implications of a (semi-)sedentary group of people highlight how we perceive these early Scandinavian populations. Moving from an interpretation of highly mobile groups following terrestrial animals across the landscape to the idea that at least some groups of people, even at this early date, lived a less mobile life, adds a new dimension to the discussion of the society in general. If aquatic resources are acknowledged as an important element in the diet of the Early Mesolithic societies, patterns of aquatic exploitation could be detected at the inland sites commonly associated with terrestrial big-game hunting. These patterns could in the future include the identification of stone tools used for handling fish. This could also include a reinterpretation of known sites to see how they were located (in terms of distance to a water body), how they were excavated (what sieving protocols were used), and an analysis of the fish bones, often present but seldom fully analysed. The reanalysis of human collagen in light of this is important, if placed in the context of isotope signals from the local fauna at each site. A heavier reliance on aquatic resources also affects patterns of movement, the ability to stay sedentary during longer time periods, and the possibility of sustaining larger populations in smaller areas than otherwise possible. This is demonstrated in the Sunnansund case, where, depending on the rate of taphonomic loss, the fish caught at the site would have been enough to feed between 100 people for more than 3 years, and up to 100 people living at the site all year around for 337 years.

The need for demonstrating a high aquatic reliance is therefore essential for our understanding of population density, movement patterns, and sedentism, as these are social and cultural expressions and choices that can be altered according to the amount of available food. A higher intake of fish implies a higher population density, with a more sedentary lifestyle combined with less movement through the landscape. Furthermore, an aquatic diet has recently been argued as a key component in human brain development and as an indicator that early hominids were able to live a more sedentary life if living off the bounty of shorebound resources (Cunnane and Crawford 2003; Cunnane 2005). Even though this comparison may be considered irrelevant, because of the enormous differences between developing early hominids and Mesolithic foragers, it highlights a general trend in archaeological research to view big-game hunting as the pinnacle of human foraging subsistence strategy. A profound understanding of the taphonomic losses and the means of accounting for them when interpreting subsistence strategies might lead to the discovery that many societies, including and predating the Mesolithic era, have relied more on aquatic resources than currently recognized. It is therefore important to start fishing for this evidence as soon as possible, because distinguishing an aquatic diet could hold the key to understanding the subsistence strategies and ways of life in the foraging past.

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References

Aaris-Sørensen, K. 1976. "A zoological investigation of the bone material from Sværdborg I–1943." *Arkæologiske Stud* 3: 137–148.

Aaris-Sørensen, K. 1983. "An example of the taphonomic loss in a Mesolithic faunal assemblage." In *Animals and Archaeology: Hunters and their Prey*, edited by C. Griegson and J. Clotton-Brock, 243–247. British Archaeological Reports International Series 163. Oxford: British Archaeological Reports.

Alley, R. B. and A. M. Ágústdóttir. 2005. "The 8k event: Cause and consequences of a major Holocene abrupt climate change." *Quaternary Science Reviews* 24: 1123–1149.

Ambrose, S. H. and M. J. Deniro. 1986. "Reconstruction of African human diet using bone collagen carbon and nitrogen isotope ratios." *Nature* 319: 321–324.

Andersen, S.H. 1995. "Coastal adaptation and marine exploitation in Late Mesolithic Denmark—with special emphasis on the Limfjord region. In *Man and Sea in the Mesolithic*, edited by Anders Fischer, 41–66. Oxbow Monograph 53. Oxford: Oxbow Books.

Arnesson-Westerdahl, A. 1984. "Den tidigmesolitiska faunan vid Hornborgasjön, Västergötland. Osteologisk analys av djurbensmaterialet från 1983 års arkeologiska undersökningar på Almeö 96 B." Unpublished report.

Berglund, B. 1964. *The Post-glacial Shore Displacement in Eastern Blekinge, Southeastern Sweden.* Sveriges Geologiska Undersökning 58:5. Stockholm: Norstedt.

Berglund, B. E., P. Sandgren, L. Barnekow, G. Hannon, H. Jiang, G. Skog and S. Y. Yu. 2005. "Early Holocene history of the Baltic Sea, as reflected in coastal sediments in Blekinge, southeastern Sweden." *Quaternary International* 130: 111–139.

Björck, S. 1995. "A review of the history of the Baltic Sea, 13.0–8.0 ka BP." *Quaternary International* 27: 19–40.

Blankholm, H. P. 2008. "Southern Scandinavia." In *Mesolithic Europe*, edited by G. N. Bailey and P. Spikins, 107–131. Cambridge: Cambridge University Press.

Boethius, A. 2016a. "Osteologiska analyser av det mesolitiska materialet." In *Norje Sunnansund. Boplatslämningar från tidigmesolitikum och järnålder. Särskild arkeologisk undersökning 2011 och arkeologisk förundersökning 2011 och 2012, Ysane socken, Sölvesborgs kommun.* Blekinge museum rapport 2014,10, edited by M. Kjällquist, A. Emilsson and A. Boethius, 145–232. Karlskrona: SHMM arkeologerna.

———. 2016b. "Something rotten in Scandinavia: The world's earliest evidence of fermentation." *Journal of Archaeological Science* 66: 169–180.

———. 2017. "Signals of sedentism: The use of the environment as evidence of a delayed-return economy in Early Mesolithic south eastern Sweden." *Quaternary Science Reviews* 162: 145–168.

———. 2018. "Huseby Klev and the quest for pioneer subsistence strategies: Diversification of a maritime lifestyle." In *Ecology of Early Settlement in Northern Europe: Conditions for Subsistence and Survival*, edited by Per Persson, Felix Riede, Birgitte Skar, Heidi M. Breivik and Leif Jonsson, 99–128. Ecology of Early Settlement in Northern Europe, Volume 1. Sheffield: Equiox Publishing.

Brinch Petersen, E. and C. Meiklejohn. 2007. "Historical context of the term 'complexity' in the southern Scandinavian Mesolithic." *Acta Archaeologica* 78: 181–192.

Broholm, H., K. Jessen and H. Winge. 1924. *Nye fund fra den ældste stenalder. Homegaard- og Sværdborg-fundene.* Copenhagen. Det Kongelige Nordiske Oldskrift-Selskab

Butler, V. L. and R. A. Schroeder. 1998. "Do digestive processes leave diagnostic traces on fish bones?" *Journal of Archaeological Science* 25: 957–971.

Cohen, J. E. and T. Fenchel. 1994. "Marine and continental food webs: Three paradoxes?" *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences* 343: 57–69.

Cordain, L., J. B. Miller, S. Eaton, N. Mann, S.H.A. Holt and J. D Speth. 2000. "Plant-animal subsistence ratios and macronutrient energy estimations in worldwide hunter-gatherer diets." *The American Journal of Clinical Nutrition* 71(3): 682–692.

Cunnane, S. C. 2005. *Survival of the Fattest: The Key to Human Brain Evolution.* Hackensack: World Scientific.

Cunnane, S. C. and M. A. Crawford. 2003. "Survival of the fattest: Fat babies were the key to evolution of the large human brain." *Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology* 136: 17–26.

Curry-Lindahl, K. 1969. *Fiskarna i färg*. Stockholm: Almqvist & Wiksell.

Davis, B., S. Brewer, A. C. Stevenson and J. Guiot. 2003. "The temperature of Europe during the Holocene reconstructed from pollen data." *Quaternary Science Reviews* 22(15–17): 1701–1716.

DeNiro, M. J. and S. Epstein. 1981. "Influence of diet on the distribution of nitrogen isotopes in animals." *Geochimica et Cosmochimica Acta* 45: 341–351.

Eidlitz, K. 1969. *Food and Emergency Food in the Circumpolar Area.* Uppsala: Almqvist & Wiksell.

Enghoff, I. B. 1987. "Freshwater Fishing from a Sea-Coastal Settlement—the Ertebölle locus classicus Revisited." *Journal of Danish Archaeology* 5: 62–76.

———. 1994. "Fishing in Denmark during the Ertebølle period." *International Journal of Osteoarchaeology* 4: 65–96.

———. 1995. "Fishing in Denmark during the Mesolithic period." In *Man and Sea in the Mesolithic*, edited by Anders Fischer, 147–160. Oxbow Monograph 53. Oxford: Oxbow Books.

———. 2011. *Regionality and biotope exploitation in Danish Ertebølle and adjoining periods.* Copenhagen: Det Kongelige Danske Videnskabernes Selskab.

Eriksson, G. 2003. *Norm and Difference: Stone Age Dietary Practice in the Baltic Region.* Stockholm. Jannes Snabbtryck Kuvertproffset

Eriksson, M. and O. Magnell. 2001. "Det djuriska Tågerup. Nya rön kring Kongemose-och Erteböllekulturens jakt och fiske." In *Tågerup. Specialstudier,* edited by P. Karsten and B. Knarrström, 15–237. Lund: UV Syd, Avd. för arkeologiska undersökningar.

Fischer, A., J. Olsen, M. Richards, J. Heinemeier, A. E. Sveinbjörnsdottir and P. Bennike. 2007. "Coast - inland mobility and diet in the Danish Mesolithic and Neolithic: Evidence from stable isotope values of humans and dogs." *Journal of Archaeological Science* 34: 2125–2150.

Fleitmann, D., M. Mudelsee, S. J. Burns, R. S. Bradley, J. Kramers and A. Matter. 2008. "Evidence for a widespread climatic anomaly at around 9.2 ka before present." *Paleoceanography* 23: 1–6.

Fuller, B. T., G. Müldner, W. Van Neer, A. Ervynck and M. P. Richards. 2012. "Carbon and nitrogen stable isotope ratio analysis of freshwater, brackish and marine fish from Belgian archaeological sites (1st and 2nd millennium AD)." *Journal of Analytical Atomic Spectrometry* 27: 807–820.

Gautier, A. 1984. "How do I count you, let me count the ways? Problems of archaeozoological quantification." *Animals and archaeology* 4: 237–251.

Grey, J., R. I. Jones and D. Sleep. 2000. "Stable isotope analysis of the origins of zooplankton carbon in lakes of differing trophic state." *Oecologia* 123: 232–240.

Gustafsson, B. G. and P. Westman. 2002. "On the causes for salinity variations in the Baltic Sea during the last 8500 years." *Paleoceanography* 17: 12:1–12:14.

Hadevik, C., K. Hammarstrand Dehman and D. Serlander. 2008. *Arkeologiska förundersökningar i form av schaktningsövervakning 2003–2007 Malmö C Nedre—i samband med byggandet av tunnel och ny stationsbyggnad*. Enheten för Arkeologi Rapport 2008, 030. Malmö: Enheten för arkeologi, Malmö kulturmiljö.

Hecky, R. and R. Hesslein. 1995. "Contributions of benthic algae to lake food webs as revealed by stable isotope analysis." *Journal of the North American Benthological Society* 14(4): 631–653.

Hedges, R. E. and L. M. Reynard. 2007. "Nitrogen isotopes and the trophic level of humans in archaeology." *Journal of Archaeological Science* 34: 1240–1251.

Iregren, E. and J. Lepiksaar. 1993. "The mesolithic site in Hög in a south Scandinavian perspective—A snap shot from early Kongemose culture." *Zeitschrift für Archäologie* 27: 29–38.

Jansson, P., F. Larsson, A.-K. Lövgren, H.Rommedahl, S. Knöös and J. Mårtensson. 1998. "Osteologisk analys av den mesolitiska lokalen Ringsjöholm." Unpublished exam paper archaeological department. Lund: Lund University

Jochim, M.A. 2011. "The Mesolithic." In *European Prehistory*, edited by S. Milisauskas, 115–142. New York: Springer.

Johansen, F. 1919. *En boplads fra den ældste stenalder I Sværdborg mose.* Copenhagen: Det Kongelige Nordiske Oldskrift-Selskab

Jones, A. K. 1986. "Fish bone survival in the digestive systems of the pig, dog and man: Some experiments." In *Fish and Archaeology,* edited by D. C. Brinkhuizen and A. T. Clason, 53–61. Oxford: Archaeopress.

Jones, A. K. ed. 1999. "Walking the cod: An investigation into the relative robustness of cod, Gadus morhua, skeletal elements." *Internet Archaeology 7.* http://dx.doi.org/10.11141/ia.7.10

Jonsson, L. 1996. *Fauna och landskap i Göteborgstrakten under boreal tid. Djurbensfynden från den boreala kustboplatsen vid Balltorp, Mölndals kommun, Västergötland.* Riksantikvarieämbetet UV Väst Rapport 1996:25

———. 2014. "Osteologisk analys—djurbenen från den preboreala kustboplatsen i Balltorp, RAÄ 182 i Mölndal, Västergötland." In *En 10 000 år gammal boplats med organiskt material i Mölndal; Ytterligare en överlagrad Sandarnaboplats vid Balltorp Västra Götalands län, Västergötland, Mölndal stad, Balltorp 1:124, Mölndal 182*, edited by G. Johansson. Riksantikvarieämbetet UV-väst rapport, 2014:91. Mölndal.

Karsten, P., B. Knarrström and S. Hyll. 2003. *The Tågerup excavations.* Lund: Riksantikvarieämbetet, UV Syd, Avd. för arkeologiska undersökningar.

Katzenberg, M. A. 1989. "Stable isotope analysis of archaeological faunal remains from southern Ontario." *Journal of Archaeological Science* 16: 319–329.

Katzenberg, M. A., O. Goriunova and A. Weber. 2009. "Paleodiet reconstruction of Bronze Age Siberians from the mortuary site of Khuzhir-Nuge XIV, Lake Baikal." *Journal of Archaeological Science* 36: 663–674.

Katzenberg, M. A. and A. Weber. 1999. "Stable isotope ecology and palaeodiet in the Lake Baikal region of Siberia." *Journal of Archaeological Science* 26: 651–659.

Kjällquist, M., A. Boethius and A. Emilsson. 2016. *Norje Sunnansund. Boplatslämningar från tidigmesolitikum och järnålder. Särskild arkeologisk undersökning 2011 och arkeologisk förundersökning 2011 och 2012, Ysane socken, Sölvesborgs kommun*. Blekinge museum rapport 2014,10. Karlskrona: SHMM arkeologerna.

Kjällquist, M. forthcoming. "Norje Sunnansund—en större boplats nära havet omkring 7000 f Kr." In *E22 Project, Sölve-Stensnäs, project synthesis*, edited by E. Rudebeck and M. Anglert.

Kleanthidis, P., A. Sinis and K. Stergiou. 1999. "Length-weight relationships of freshwater fishes in Greece." *Naga, The ICLARM Quarterly* 22: 37–40.

Koutrakis, E. and A. Tsikliras. 2003. "Short Communication. Length–weight relationships of fishes from three northern Aegean estuarine systems (Greece)." *Journal of Applied Ichthyology* 19: 258–260.

Kullander, S., L. Nyman, K. Jilg and B. Delling. 2012. *Ryggsträngsdjur. Strålfeniga fiskar. Chordata: Actinopterygii.* Nationalnyckeln till Sveriges flora och fauna. Uppsala: SLU.

Lagerås, P. A. Broström and N.-O. Svensson. forthcoming. "Insamling av ätliga växter och ved under mesolitikum. En diskussion baserad på makrofossil och träkol från västra Blekinge." In *E22 Project, Sölve-Stensnäs, project synthesis*, edited by E. Rudebeck and M. Anglert.

Larsson, L. 1978. "Mesolithic antler and bone artefacts from Central Scania." *Meddelanden från Lunds universitets historiska museum* 1977–1978: 28–67.

Leduc, C. 2012. "Ungulates exploitation for subsistence and raw material, during the Maglemose culture in Denmark: The example of Mullerup site (Sarauw's Island) in Sjælland." *Danish Journal of Archaeology* 1: 62–81.

Lepiksaar, J. 1978. "Bone remains from the Mesolithic settlements Ageröd I:B and Ageröd I:D." In *Ageröd I:B–Ageröd I:D : A Study of Early Atlantic Settlement in Scania,* edited by L. Larsson, 234–244. Acta Archaeological Lundensia Series. Lund: C.W.K. Gleerup.

———. 1982. "Djurrester från den tidigatlantiska boplatsen vid Segebro nära Malmö i Skåne (Sydsverige)." In *Segebro: En tidigatlantisk boplats vid Sege å mynning,* edited by L. Larsson, 105–128. Malmöfynd 4. Malmö: Malmö Museum.

———. 1983a. "Animal remains from the atlantic bog site at Ageröd V in central Scania." In *Ageröd V: An Atlantic bog site in central Scania,* edited by L. Larsson, 159–168. Acta archaeologica Lundensia. Series in 8°. Lund: Lund Institute of Archaeology.

———. 1983b. "Zoologisk undersökning." In *Bua Västergård — en 8000 år gammal kustboplats*, edited by J. Wigforss, J. Lepiksaar, I. U. Olsson and T. Påsse, 115–161. Arkeologi i Västsverige 1. Göteborg: Göteborgs Arkeologiska Museum.

Magnell, O. 2006. *Tracking Wild Boar and Hunters: Osteology of Wild Boar in Mesolithic South Scandinavia*. Lund: Lund University.

———. nd. "Climate change at the Holocene Thermal Maximum and its Impact on Wild Game Populations in South Skandinavia." Manuscript.

Magnussen, B. 2007. "En geologisk og zooarkæologisk analyse af kystbopladsen; Lollikhuse på overgangen mellem Mesolitikum og Neolitikum." Unpublished seminar paper, University of Copenhagen.

Marlowe, F. W. 2005. "Hunter–gatherers and human evolution." *Evolutionary Anthropology: Issues, News, and Reviews* 14: 54–67.

Milner, N. O. Craig, G. Bailey, K. Pedersen, S. H. Andersen. 2004. "Something fishy in the Neolithic? A re-evaluation of stable isotope analysis of Mesolithic and Neolithic coastal populations." *Antiquity* 78(299): 9–22.

Møhl, U. 1984. "Dyreknogler fra nogle af borealtidens senere bopladser i den sjællandske Aamose." *Aarbøger for Nordisk oldkyndlighed og historia* 1984: 47–60.

Morales, A., E. Roselló and P.M. Ruíz. 2001. "A renewable fish exploitation model for application on ichthyoarchaeological assemblages." *Animals and Man in the Past, Groningen, ARC-Publicatie* 41: 44–52.

Morales, A. and K. Rosenlund. 1979. *Fish Bone Measurements: An Attempt To Standardize the Measuring of Fish Bones from Archaeological Sites*. Copenhagen: Steenstrupia.

Moyle, P. B. and J. J. Cech. 2004. *Fishes: An Introduction to Ichthyology*. Upper Saddle River, NJ: Pearson Prentice Hall.

Neophytou, C. 1993. "Ecological study of the perch (*Perca fluviatilis*) in Doirani lake." *Greek Geotech Sci Iss.* 4: 38–47.

Nicholson, R. 1993. "An investigation into the effects on fish bone of passage through the human gut: some experiments and comparisons with archaeological material." *Circaea* 10: 38–51.

Nilsson, B. 2012. "Flooded Stone Age–Towards an overview of submerged settlements and landscapes on the continental shelf." *The European Archaeologist* 38: 84–85.

Noddle, B. A. 1977. "Mammal bone." In *Excavations in King's Lynn, 1963-1970*, edited by H. Clarke and A. Carter, 378–399. London: Society for Medieval Archaeology.

Noe-Nygaard, N. 1995. *Ecological, Sedimentary and Geochemical Evolution of the Late-glacial to Post-glacial Åmose Lacustrin Bay, Denmark*. Fossils and Strata 37. Copenhagen: Scandinavian University Press.

O'Connell, T., C. J. Kneale, N. Tasevska and G.G.C. Kuhnle. 2012. "The diet–body offset in human nitrogen isotopic values: A controlled dietary study." *American Journal of Physical Anthropology* 149(3): 426–434.

Pedersen, L. 1995. "7000 years of fishing: Stationary fishing structures in the Mesolithic and afterwards." In *Man and Sea in the Mesolithic*, edited by Anders Fischer, 75–86. Oxbow Monograph 53. Oxford: Oxbow Books.

Rasmussen, S. O., B. M. Vinther, H. B. Clausen and K. K. Andersen. 2007. "Early Holocene climate oscillations recorded in three Greenland ice cores." *Quaternary Science Reviews* 26(15–16): 1907–1914.

Richards, M. and D. Price. 2003. "Mesolithic and Neolithic subsistence in Denmark: New stable isotope data." *Current Anthropology* 44: 288–295.

Rosenlund, K. 1971. "Zoological material." In *Sværdborg II, A Maglemose hut from Sværdborg bog, Zealand, Denmark*, edited by E. Brinch Petersen, 59–62. Acta Archaeologica, XLII. Copenhagen: Munksgaard.

———. 1980. "Knoglematerialet fra bopladsen Lundby II." In *Lundby-holmen: Pladser af Maglemose-type i Sydsjælland*, edited by B. Henriksen, 128–142. Copenhagen: Nordiske Fortidsminder.

Rowley-Conwy, P. and M. Zvelebil. 1989. "Saving it for later: Storage by prehistoric hunter-gatherers in Europe." In *Bad Year Economics: Cultural Responses to Risk and Uncertainty,* edited by P. Halstead and J. O'Shea, 40–56. Cambridge University Press.

Sarauw, G. 1903. *En stenalders boplats i Maglemose ved Mullerup, Sammenholt med beslægtede fund. Bidrag til belysning af nystenalderens begyndelse i Norden.* Copenhagen: Aarbøger for Nordisk oldkyndighed og historie.

Seifert, T., F. Tauber and B. Kayser. 2001. "A high resolution spherical grid topography of the Baltic Sea," 2nd edition, Baltic Sea Science Congress, Stockholm, 25–29 November 2001, Poster# 147. www.iowarnemuende.de/iowtopo.

Stewart, K. M. and D. Gifford-Gonzalez. 1994. "An ethnoarchaeological contribution to identifying hominid fish processing sites." *Journal of Archaeological Science* 21: 237–248.

Tauber, H. 1981. "13C evidence for dietary habits of prehistoric man in Denmark." *Nature* 292: 332–333.

Thieren, E., W. Wouters, W. Van Neer and A. Ervynck. 2012. "Body length estimation of the European eel Anguilla anguilla on the basis of isolated skeletal elements." *Cybium* 36(4): 5

Van Der Merwe, N. J. and J. C. Vogel. 1978. "13C content of human collagen as a measure of prehistoric diet in Woodland North America." *Nature* 274: 815–816.

Vogel, J. C. and N. Van Der Merwe. 1977. "Isotopic evidence for early maize cultivation in New York State." *American Antiquity* 42: 238–242.

Webb, E. C., N. V. Honch, J. Dunn, G. Eriksson, K. Lidén and R. Evershed. 2015. "Compound-specific amino acid isotopic proxies for detecting freshwater resource consumption." *Journal of Archaeological Science* 63: 104–114.

Wheeler, A. and A. K. Jones. 1989. *Fishes.* Cambridge: Cambridge University Press.

Willis, D. W. 1989. "Proposed standard length–weight equation for northern pike." *North American Journal of Fisheries Management* 9: 203–208.

Paper IV

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Huseby Klev and the Quest for Pioneer Subsistence Strategies: Diversification of a Maritime Lifestyle

Adam Boethius

The bone material from three archaeological occupation phases at Huseby Klev provides the best source of evidence currently available about the subsistence strategies of pioneer settlers in Northern Europe. The results from Huseby Klev indicate that the pioneer settlers initially relied heavily on marine mammals for their sustenance. This subsistence strategy changed during the second and third occupation phases of the site, during which fishing became the most important part of the diet. These changes in subsistence strategy are interpreted as arising from different factors. A highly nutritious ocean on the west coast of Scandinavia at the end of the last ice age resulted in large numbers of available marine mammals in the ocean, which supported a large human population able to base its economy on them. As the ocean became less nutritious with the cessation of freshwater mixing, the marine mammals suffered a natural population decline, while humans still relied upon them heavily, resulting in a marine-mammal collapse. This forced the human populations to change their subsistence strategy, and fish became dominant in the diet. The bone material from Huseby Klev implies a good knowledge of fishing methods and seafaring, in addition to which it highlights the ocean as the main source of sustenance during the time from the Preboreal–Boreal transition to the mid Atlantic chronozone. The hunting of terrestrial mammals, also found on the site, is interpreted as mainly being undertaken to supply raw material. Finds of reindeer imply the presence of reindeer in Mesolithic western Scandinavia, but they were not prioritized in the diet, possibly only being exploited during yearly migrations. Birds are common in the bone material, and a large number of bird species with a low number of identified fragments from each species implies opportunistic hunting of all but auks, which were hunted in large numbers. The bone material from Huseby Klev is the oldest and best-preserved Atlantic coastal material in Europe, and the results indicate an advanced knowledge of utilizing aquatic resources and suggest a boom in aquatic reliance that is earlier and more widespread than previously known.

Introduction

Huseby Klev is a well-known archaeological site, mainly because it is the earliest known coastal site from Europe with organic remains. The site is located on Orust (Figure 5.1), an island within the coastal archipelago about 50 km north of modern-day Gothenburg, on the west

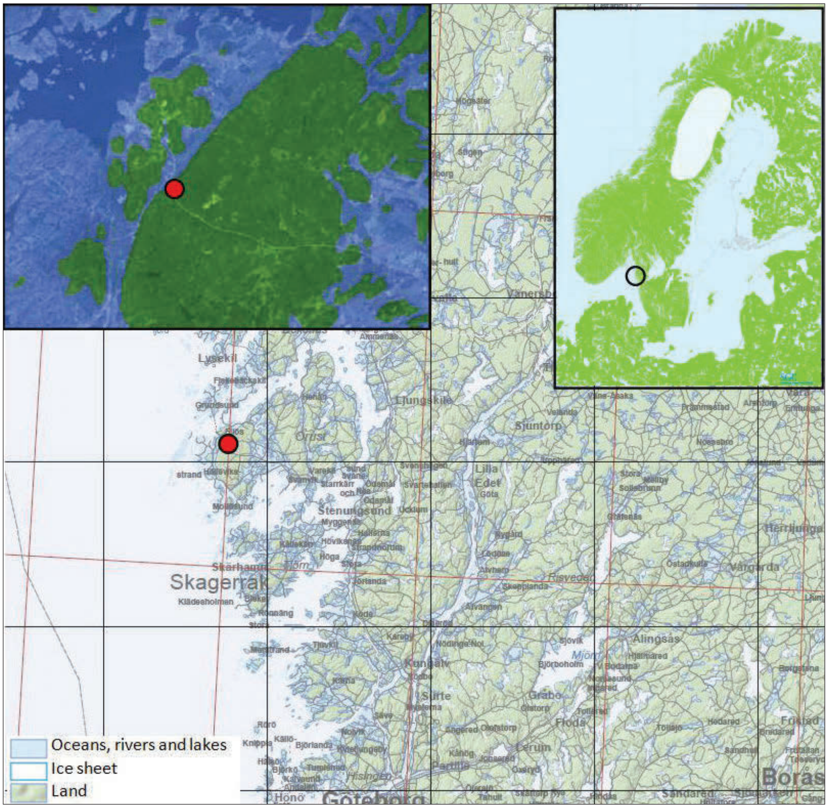

Figure 5.1 The red dot indicates the location of Huseby Klev, dated to 8000 cal BC; for the main picture the scale is 1:500,000; for the upper left inset the scale is 1:25,000; the upper right inset indicates the location in Sweden. The map is based on terrain models using topographic information from the Swedish Geological Survey (© SGU).

coast of Sweden. The site was excavated between 1992 and 1994, and the results were later published as a report (Nordqvist 2005). A preliminary osteological analysis by Leif Jonson was included in the report, indicating roughly what species were present at the site (Jonsson 2005). However, because the report did not include any quantification or description of how much of the excavated material was included in the analysis, it has been difficult to use the data to investigate subsistence strategies. As the material from Huseby Klev is unique and provides the earliest organic evidence from Scandinavian west-coast settlements, a new analysis was warranted. Therefore, an analysis of the entire Mesolithic bone material was carried out by four bachelor degree students of historical osteology at Lund University, Sweden, under the supervision of the author. The aim of the analysis was to quantify the material, and the results of this paper are based on their determinations and quantifications (Christensson 2015; Hellgren 2015; Nemecek 2015; Widmark 2015), and the comparative use of other contemporaneous sites with preserved organic material.

The bone material from Huseby Klev derives from three different Mesolithic occupations on the same site. This permitted assessment of any chronological changes in the environment and human activity. Furthermore, the oldest phase includes the oldest known bone material from the Scandinavian west coast, with a sufficient amount of preserved material to assess the diet and lifestyle of the first settlers of Northern Europe. The bone material from Huseby Klev therefore has the potential to further our knowledge of the Scandinavian pioneers and answer questions regarding their subsistence strategies, and how and why these strategies changed and developed over time.

Material

The analysed Mesolithic bone material from Huseby Klev consists of 11.9 kg of relatively fragmented, often fluvially affected, mostly unburnt bone and antler. This does not include an unspecified quantity of bone artefacts, or the bones removed for ancient DNA and isotope analysis prior to the osteological analysis. The bone material derives from three different occupations, chronologically placed at the transition between the Preboreal and Early Boreal chronozone (PBO–EBO), radiocarbon dated to about 8300–7600 cal BC, the mid Boreal chronozone (MBO), radiocarbon dated to about 7600–6700 cal BC, and the mid Atlantic chronozone (MAT), radiocarbon dated to about 6000–5700 cal BC. The two earliest settlements have been superimposed with postglacial clay: the PBO–EBO material is located in a sandy shell-clay layer and the material from the MBO is located in a sandy shell layer. The MAT material derives from a hut structure, two ditches associated with the hut, and a cultural layer surrounding the structures, all filled with oyster shell remains (Nordqvist 2005).

No spatial analysis was attempted, as the focus of the study was to analyse the overall trends. The variation in the types of contexts within the different occupation phases may have had an

	Dating (cal BC)	Total No. of fragments	Weight (kg)	NISP	Human	Ungulate	Fur game	Marine mammal	Micro-rodentia	Bird	Amphibia	Fish*
PBO-EBO	8300–7600	2156	4.5	712	2	130	28	206		77	1	268
MBO	7600–6700	5465	5	774	0	100	44	5	2	50	0	573
MAT	6000–5700	5403	2.3	688	0	114	41	14	8	15	0	496

Table 5.1 The bone material from Huseby Klev with quantification based on number of identified specimens (NISP), not including bone artefacts or bones removed for aDNA prior to the analysis. *Randomly analysed fish bones: the majority of the fish bones had not been counted or analysed and were not included; the quantity analysed amounted to around 66% of the fish bones from the PBO–EBO and to about 5% each from the MBO and MAT.

impact on the nature of the bone assemblages, as different areas might have functioned differently and therefore contained different artefacts. However, these possible anomalies were disregarded in the overall interpretation in order to maximize the use of the data.

The bone material consisted of 13,024 fragments, of which 2,174 fragments were identified to species or family level (Table 5.1). The bulk of the fish bone material was not analysed or quantified, and only a selected number of fish bones were chosen randomly for analysis. A comprehensive analysis of the fish bone material is currently being carried out and will be published separately.

Method

The material was analysed using the comparative collection at the Department of Archaeology and Ancient History at Lund University, with the additional use of collections from the Biological Museum at Lund University and the Zoological Museum at Copenhagen University (Denmark).

Age determinations were mainly based on epiphyseal fusion and loose teeth, as complete mandibles were missing in the material. For wild boar (*Sus scrofa*), age determination was based on epiphyseal fusion according to Bull and Payne (1982). For roe deer (*Capreolus capreolus*), tooth wear was assessed according to Habermehl (1961) and using mandibular age ladders (a sequence of mandibles from animals with known age) from Copenhagen Zoological Museum. Red deer (*Cervus elaphus*) age estimation was based on epiphyseal fusion. However, because no comprehensive study exists, three different studies were used to incorporate the entire red deer skeleton. Bosold (1966) was used for the phalanges and metapodials, Lyman (1991) for the humerus, femur, radius, and tibia, and Heinrich (1991) for the rest of the body. The lack of a comprehensive epiphyseal growth study for red deer is problematic, as is the use of single teeth for roe deer, compared to mandibular age ladders, and thus the ages determined for these two species should be regarded as general trends. Seal age determination was based on epiphyseal fusion according to Storå (2001). Age determination for white-beaked dolphin (*Lagenorhynchus albirostris*) and porpoise (*Phocoena phocoena*) was based on epiphyseal growth of the common bottlenose dolphin (*Tursiops truncatus*) according to Costa and Simões-Lopes (2012).

Because of the low number of sex-determinable bone fragments, this potential aspect of the subsistence strategies had to be disregarded.

The element distribution pattern has been examined by dividing the skeletal elements of the body into five regions: *antler*; *cranium*—skull, mandible, and loose teeth; *limb bones*—scapula, humerus, radius, ulna, femur, tibia, and fibula; *body core*—ribs, vertebrae, and pelvis; and *distal extremities*—carpals, tarsals, metapodials, and phalanges. This division is based on ethnographic dismembering and butchering patterns (Binford 1981).

The epithet “fur game” is used as a collective noun and encompasses all non-ungulate terrestrial mammals, including dogs, hedgehogs, and water voles, even though dogs were not necessarily used primarily for their fur, hedgehog skin is not a traditional fur, and water vole can, but does not have to, be an intrusive rodent. The use of this epithet was pragmatic, to reduce the number of categories for analysis and because some dog bones bear traditional skinning and butchery marks (Eriksson and Magnell 2001a, 58; Noe-Nygaard 1995), and because hedgehogs and water voles are often actively hunted. None of the other small rodents found on the site were included in the study, because indications of human utilization in the form of cut marks and burning have only been found on water vole (Boethius 2016a; Noe-Nygaard 1995) and not on any other micro-rodent (*Cricetidae*) from comparable archaeological sites.

Although many bird fragments were identified, further effort would have provided a greater return. However, because of time constraints, the largest and best-preserved bird fragments were prioritized for identification. Therefore, further bird bone analysis is warranted.

The fish bones have not yet been analysed comprehensively; however, while a complete analysis is being carried out and will be published separately, the need for some indication of fish bone abundance on the site is crucial for a meaningful discussion of the subsistence strategies presented in this paper. Unfortunately, fish bones have been more or less neglected in many studies from contemporaneous sites, and usually only the number of identified fragments has been published, without any information regarding the weight or the number of unidentified fish fragments. Therefore, rough estimates were needed to approximate the number of fish bones in order to make them somewhat comparable with other sites and further the discussion. The estimates were based on the weight of the total amount of fish bone divided by the weight of the identified fish bone. Estimates regarding the number of potentially identifiable fragments were based on the 82% identification rate of the fish bone assemblage from Sunnansund (Boethius 2016a). As the fish bones are used here mainly as a means of furthering the discussion of the results, rough estimates were sufficient to illustrate overall trends. Furthermore, since most of the earth was excavated using 5 mm water sieves (Nordqvist 2005, 17), the majority of the potential fish bone will not have been recovered. This is most apparent when looking at the abundance of smaller fish, such as herring, which was only found in macro-samples (bags of recovered soil), sifted with fine-mesh sieves. Studies from Sunnansund indicate that the difference in quantity lost between using a 2.5 mm sieve and a 5 mm sieve is about 94%. When comparing these two mesh sizes by splitting material from a single homogeneous feature at Sunnansund in half, the number of identified fish bones found with the 5 mm sieve was 418 fragments, while the number from the 2.5 mm sieve was 6,761 identified fragments (Boethius 2016b). A similar experiment was conducted more than 30 years ago with material from a marine environment on the coast of Norway, albeit with remains from a different time period. In this experiment the researchers evaluated the gain in using sieves when excavating faunal material and were able to identify 3,553 fish bones to species level when using fine-meshed sieves (1 mm) and only 118 fish bones from the same context when not using a sieve, which is a difference of more than 96% (Hultgreen *et al.* 1985). An even larger loss of fish bones is noted from the Viking Age site of Viborg in Denmark. Here, only 6 fish bones were found when excavated by hand-collection, while 3,651 fish bones were found when the same soil was sieved with a 3 mm sieve; implying a 99.84 % loss (Enghoff 2007). As the smaller-sized fish from Huseby Klev were only present in the macro-samples passed through a fine-mesh sieve, this implies that the quantity of recovered fish would have been much greater if smaller mesh sizes had been used for larger areas of the excavation surface, further highlighting the importance of fish in the diet.

Results

The occupation phases at Huseby Klev were dissimilar from each other, and the bone assemblages indicated different subsistence strategies. The dietary remains from the PBO–EBO phase were dominated by aquatic mammals; fish was included in the diet, although in small quantities and therefore of less dietary importance compared with later phases. In both the MBO and the MAT phases of Huseby Klev, ungulate hunting initially appeared to have replaced marine mammals (Figure 5.2). However, when fish was included in the analysis it was apparent that the degree of ungulate hunting was approximately the same in all three phases and that the marine mammals had been replaced by fish (Figure 5.3). Fur game was present in all phases, with a distribution comparable with many contemporaneous sites. Fur game as well as ungulates appeared to be more frequent in the later phases, but this was an artefact of the large number of marine mammals in the earliest phase, which reduced the relative frequency of all other types of animals. An interesting aspect of the species distribution was the overall high frequency of bird bones, which differed from most comparable settlements and indicated a greater reliance on birds.

The extreme outliers for both Sunnansund and Huseby Klev (Figure 5.3), compared with all the other sites, are obvious. However, what the data are actually showing is the result of a combination of three major taphonomic processes: preservation, recovery, and analysis.

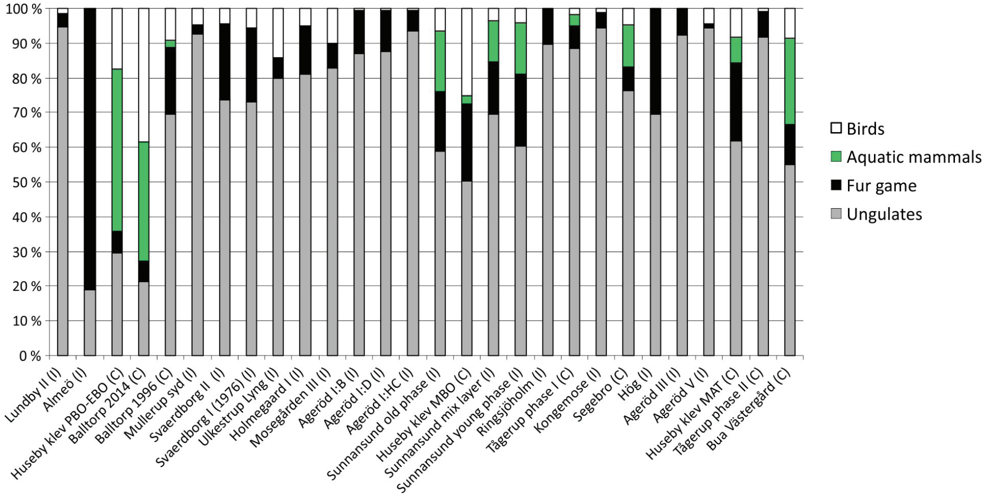

Figure 5.2 A comparison of the amount of identified bone fragments from south Scandinavian Early and Middle Mesolithic sites based on % NISP, not including fish. (I) inland settlement (aquatic resources from freshwater environments); (C) coastal settlement (aquatic resources from marine environments). The sites are showed in chronological order: Lundby II (Rosenlund 1980), Almeö (Arnesson-Westerdahl 1984), Balltorp (Jonsson 1996; 2014), Mullerup (Leduc 2012; Sarauw 1903), Sværdborg (Aaris-Sørensen 1976; Johansen 1919; Rosenlund 1971), Ulkestrup Lyng (Noe-Nygaard 1995), Holmegaard I (Broholm *et al.* 1924), Mosegården III (Møhl 1984), Ageröd I:B, I:D, I:HC, III, V (Larsson 1978; Lepiksaar 1978; 1983b; Magnell 2006, 2017, forthcoming, a), Sunnansund (Boethius 2017), Tågerup (Eriksson and Magnell 2001b), Kongemose (Noe-Nygaard 1995), Segebro (Lepiksaar 1982), Hög (Iregren and Lepiksaar 1993), Bua Västergård (Lepiksaar 1983a).

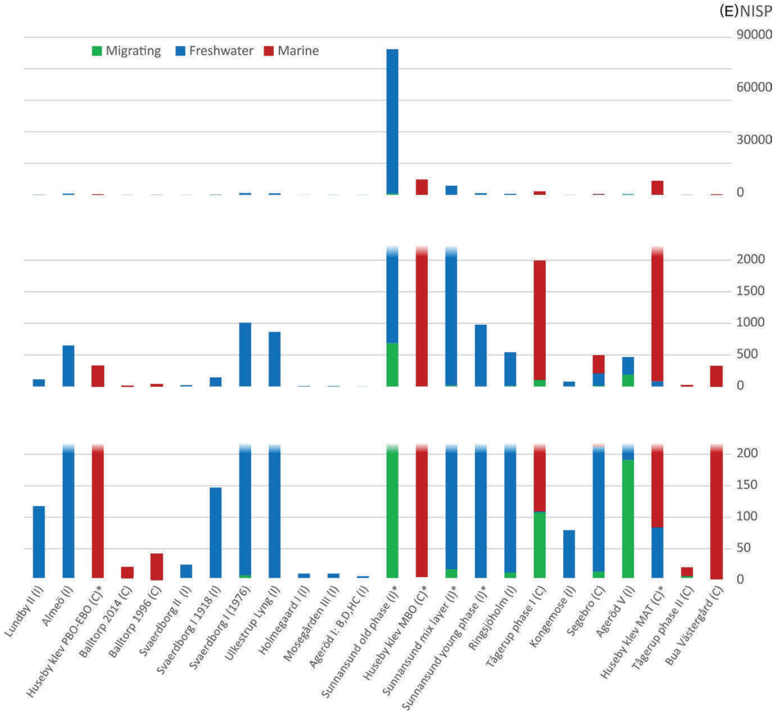

Figure 5.3 Number of identified fish bones from migrating, freshwater, and marine fish. *Estimated number of identified fragments (ENISP), had the entire fish bone material been analysed. The top part shows unaltered (E)NISP; the bottom part shows the same data at a higher resolution to show the number of fish bones without the outliers of Sunnansund and Huseby Klev. Sites displayed in chronological order.

Fish bones are more sensitive to bad preservation conditions, and small changes in the soil environment cause fish bones to disintegrate more quickly than mammal bones. Furthermore, none of the material considered had been similarly and comparably excavated; sieves had not been used at all the sites, and if they were used, mesh sizes varied. Finally, not all of the fish bone material from the different sites had been comprehensively analysed and quantified, and because the illustration is based on the number of identified specimens, and no material other than Huseby Klev and Sunnansund has provided an estimated number of determinable fish bones (ENISP), Figure 5.3 can be used to provide an indication of the substantial taphonomic losses that occur when dealing with archaeological fish remains. This is further demonstrated in Boethius (2018), as the taphonomic loss of fish bone is huge even on sites with very good preservation that have been excavated with the recovery of fish bones in mind. Therefore, if no taphonomic agent had influenced the remains, the assemblages would have displayed a larger proportion of fish bones, possibly with even greater numbers than Sunnansund. However, based on the available material, the nutritional input from fish in the diet and its importance for subsistence remains unresolved for all sites except Huseby Klev and Sunnansund.

Ungulates

Five ungulate species were identified at Huseby Klev: red deer, roe deer, wild boar, reindeer, and elk (Table 5.2). There were diachronic differences regarding what ungulate species were the most common game, varying from wild boar in the PBO–EBO to roe deer in both the MBO and MAT.

It is important to remember that Huseby Klev is located on an island, which will have limited the number of available ungulates. Even though Orust is a large island, the need for supplies would have required people to hunt on the mainland for some of the ungulate species. This is probably why aurochs was not present in the bone material, as their size and slow reproduction would have made it hard for them to survive on the island if subjected to hunting. Their large size also means it is unlikely their carcasses were dragged or carried over long distances, following the general rules of the Schlepp effect (Binford 1978; Lupo 2006; Perkins and Daly 1968; White 1952). Elk is seen at a constantly low frequency and completely lacking in the MBO, probably for the same reasons as aurochs. Red deer was present at a roughly constant level across the phases, although it was the second most common ungulate during both the PBO–EBO and MAT and the least common ungulate during the MBO. The presence of reindeer in the PBO–EBO assemblage is of note. Even though reindeer is present in Late Pleistocene and Early Holocene bogs in the more southerly parts of Scandinavia (Aaris-Sørensen *et al.* 2007; Larsson 2012; Liljegren and Ekström 1996), this is the earliest evidence of reindeer bones at an archaeological settlement this far north. Populations of reindeer were probably not present on the island, even though the species is good at swimming and individuals may have crossed the straits; carcasses were probably brought across from a kill site off the island. However, as both antler (Figure 5.4) and part of a pelvic bone were present the actual kill site was probably not too far away.

The hunting pattern for red deer is difficult to study, since the PBO–EBO did not have any bones from the first-year category and the MBO had only one fragment. There seems to be a difference between the PBO–EBO and MBO regarding the older age classes; however, the low number of bones of determinable age, three from the PBO–EBO and six from the MBO, complicates interpretations (Figure 5.5).

Roe deer hunting could only be assessed for the MAT. Tooth wear analysis (Figure 5.6) indicates a low outtake of juvenile individuals, with an increasing hunting pressure on 2–4 year olds, a lesser outtake between the ages of 4 and 7, and the oldest roe deer about 10 years old at death.

Table 5.2 Number of identified ungulate specimens and their abundance in the three different phases of Huseby Klev.

	Red deer (*Cervus elaphus*)	**Wild boar** (*Sus scrofa*)	**Roe deer** (*Capreolus capreolus*)	**Elk** (*Alces alces*)	**Reindeer** (*Rangifer tarandus*)	**Total**
PBO-EBO	31	81	11	4	3	130
MBO	16	40	44			100
MAT	33	24	54	3		114

Figure 5.4 The double curvature of the Huseby Klev antler is typical for a reindeer antler tip and not present on any other cervid species. Also notice the sectioned antlers: elk has no trabecular tissue; red deer has small areas of compact bone and large areas of trabecular bone; reindeer has a medium degree of compact bone, and the trabecular bone tissue is made of small spongy holes. This makes the Huseby Klev antler the first identified reindeer fragment from a Scandinavian coastal archaeological context and the earliest ever at a Swedish archaeological settlement.

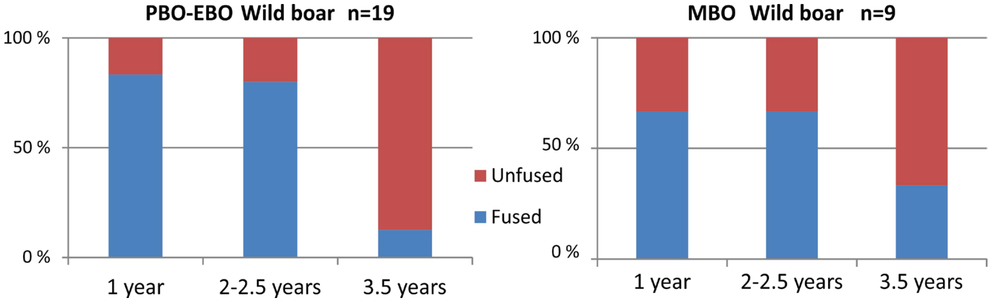

Figure 5.5 Wild boar bones from the PBO–EBO and MBO phases: fused and unfused bones aged 1 year (scapula, distal humerus, proximal radius, acetabulum, proximal phalanx 2), 2–2.5 years (distal metapodials, distal tibia, proximal phalanx 1, proximal fibula, calcaneus), and 3.5 years (proximal ulna, proximal humerus, distal radius, femur, proximal tibia, distal fibula, vertebrae).

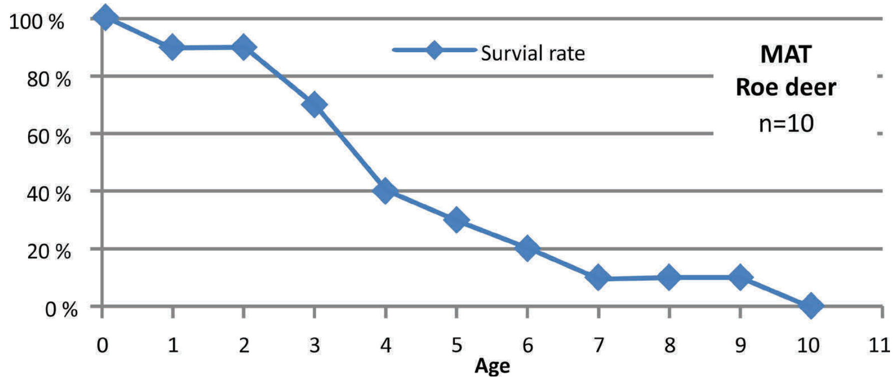

Figure 5.6 Roe deer survival rate in the MAT, based on mandibular tooth wear compared with an age-wear ladder.

Ungulate element distribution varies between the different species and phases, and while most parts of the ungulate bodies are represented in the material, some patterns can be discerned (Figure 5.7).

In the PBO–EBO a more diverse element distribution is apparent, indicating that most parts of the body were transported back to the settlement, which suggests a broad use of the bodies. In the MBO and MAT the elements from the body core generally appear in relatively low frequencies, and in the MAT the limb bones are also less frequent. This could partly be explained by taphonomic factors, because the elements from the body core preserve worse than the bones from other, more massive body regions. However, fish bones are abundant in these contexts and they preserve worse than body core elements. It is therefore likely that the utilization pattern changed so that only the more useful body parts were brought back to the settlement; the many skull fragments (mostly teeth) therefore represent skulls being brought to the settlement while still attached to the skin, a practice also seen in other archaeological foraging contexts (Turnbull and Reed 1974).

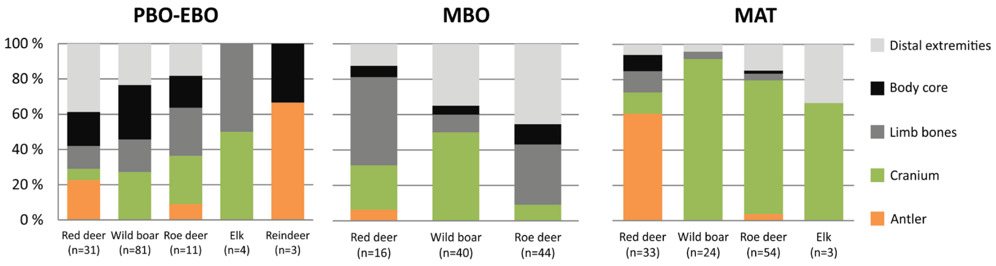

Figure 5.7 Element distribution of the ungulate species from the three different occupation phases at Huseby Klev.

Fur game

There were 12 species of fur game identified in the assemblages (Table 5.3). Although a fair number of fur game species could be identified, they only made up a small portion of the identified fragments; they are considered to be of minor dietary importance and in all phases mainly hunted for their fur.

There were differences in the element distribution of the fur game species between the different occupation phases (Figure 5.8). In general, the two oldest phases contained a wider representation of different body parts. However, if the species are viewed separately, larger discrepancies between the species and the different occupations emerge. An overrepresentation of distal extremities is often an indication that an animal was skinned at a kill site and only the fur with the distal extremities and sometimes the skull attached brought back to the site; this appears to be the case in the PBO–EBO phase for brown bear and beaver. In the MBO phase it appears that the most common strategy for dealing with red fox and wild cat was to bring the

Table 5.3 Number of identified fur game specimens.

	PBO-EBO	MBO	MAT
Wolf *(Canis lupus)*		6	
Dog *(Canis familiaris)*	3		14
Red fox *(Vulpes vulpes)*	8	12	9
Brown bear *(Ursus arctos)*	3	1	
Pine marten *(Martes martes)*	1		
Badger *(Meles meles)*	1		
Otter *(Lutra lutra)*	5	1	3
Wild cat *(Felis silvestris)*		10	1
Beaver *(Castor fiber)*	2		1
Squirrel *(Sciurus vulgaris)*		2	5
Hedgehog *(Erinaceus europaeus)*	1		1
Water vole *(Arvicola terrestris)*	4	12	7
Total fur game	28	44	41

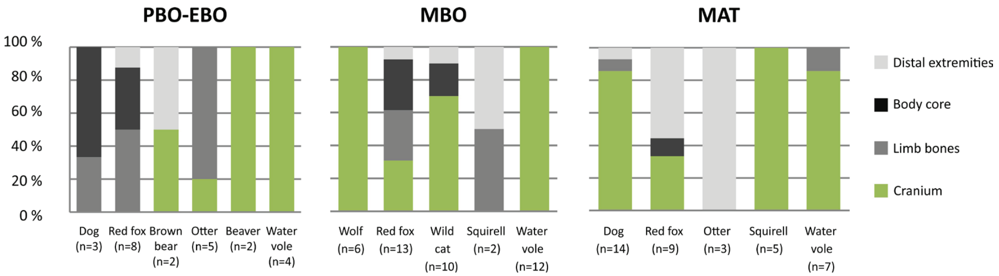

Figure 5.8 Element distribution of the fur game species from the three different occupation phases at Huseby Klev. Species with only one fragment are excluded to account for some of the problems when using small samples.

complete carcasses to the site, while wolves appear to have been skinned at the kill site and only the skull and pelt brought back to the settlement. Later, in the MAT, otters appear to have been skinned at a kill site, while foxes were still brought back to camp as complete carcasses. Furthermore, cranial fragments dominated the MAT, and loose teeth were often the major component. This could be an issue of preservation and identification, as teeth often preserve better in unburnt contexts and are easier to identify in a fragmented state. It is interesting that the most body parts are represented for both dogs and foxes in all assemblages. For dogs this makes sense, as they are likely to have been present and of use at the site as living animals. The presence of whole fox carcasses suggests that they were brought back to site before being skinned and also indicates that there may have been populations of foxes present on the island throughout the different occupation phases. The same could be said for the otter in the two earliest phases and for wild cat and squirrel in the MBO. However, again it should be noted that the sample size was limited and the numbers of identified bones were low for each species, and the observed patterns could be biased for this reason. Beaver was represented by a lower jaw and a tooth during the PBO–EBO phase and a tooth in the MAT. Beaver jaws and teeth have been used as tools (Hatting 1969) and could therefore have been brought to the site as such. However, pollen samples taken from the site indicate the presence of both oak (*Quercus*) and birch (*Betula*), and a freshwater environment (Svedhage 2005), which means it would have been possible for beavers to dwell in the area. The presence of hedgehog is of note, and the island location suggests the possibility that they were brought by humans. It has been speculated that the geographical spread of the hedgehog is partly due to human agency, because of human utilization of its fatty meat (Jonsson 1995).

Marine mammals

There were large discrepancies between the different phases regarding the use of marine mammals as a subsistence source. This is illustrated clearly in Figure 5.2, as the aquatic mammals make up a major part of the identified bones in the PBO–EBO but seem to lose their importance during the later phases. The PBO–EBO is dominated by white-beaked dolphin, followed by grey seal and harbour porpoise. This stands in clear contrast to later phases, the cetaceans being rare in the MBO and absent from the MAT (Table 5.4).

There is no apparent age pattern among the aquatic mammals identified, and all ages are present in the material, from young pups and calves of both seals and cetaceans to older individuals. This implies that active age selection was not practiced when hunting marine mammals.

Table 5.4 Number of identified marine-mammal specimens.

	White-beaked dolphin (*Lagenorhynchus albirostris*)	**Harbour porpoise** (*Phocoena phocoena*)	**Dolphins** (Delphinidae)	**Grey seal** (*Halichoerus grypus*)	**Harbor seal** (*Phoca vitulina*)	**Seal** (Phocidae)	**Total marine mammals**
PBO-EBO	140	27	4	28	4	3	206
MBO	3	1		1			5
MAT				9	5		14

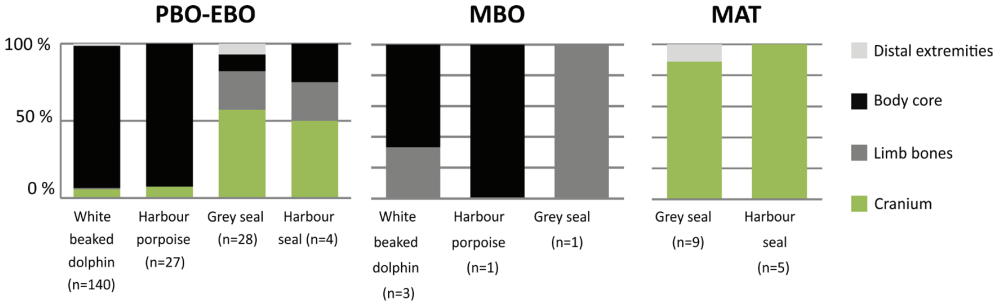

Figure 5.9 Marine-mammal element distribution from the three different occupation phases at Huseby Klev.

The element distribution differs between seals and whales (Figure 5.9). The seal bones are dominated by skull fragments, with the majority of them coming from the temporal bone in the PBO–EBO and from loose teeth in the MAT. The cetaceans are dominated by vertebral fragments, followed by ribs. The variation in element distribution is probably a result of the different morphology of seals and whales: whales have smaller and weaker teeth and lack most elements of the limb bones and the distal extremities. It is therefore unlikely that this apparent difference is the result of human activity.

Birds

There were 22 different bird species identified at Huseby Klev, of which the majority were found in the PBO–EBO, where the largest number of bird fragments have been identified (Table 5.5). The bird species found at Huseby Klev were almost exclusively coastal birds, indicating that they were hunted locally. The bird bone material has not been exhaustively analysed; therefore, further analysis of the many unidentified fragments is warranted.

Throughout the occupation phases, auks were the most-hunted bird family, notably the great auk, followed by the common murre, implying a frequent and well-planned auk hunt. Apart from the auks, the large abundance of species represented by relatively few fragments implies that birds were commonly but opportunistically hunted. Birds in general and auks in particular therefore appear to have been a common element of the human diet.

Fish

Fishing was of major importance for subsistence at Huseby Klev; as illustrated in Figure 5.3, the site contains the second most abundant fish bone assemblage ever found in Early and Middle Mesolithic Scandinavian contexts, and the biggest marine fish bone assemblage. Fishing appears to become more important during the two later occupation phases.

As only a small and inconsistently analysed part of the fish bone material has been studied so far, the number of identified specimens (Table 5.6) is not directly comparable with other sites and should only be regarded as indicating different species. However, relative abundance can be used as a measure of the importance of each order of species found at the site and, by extrapolating the estimated number of identifiable specimens, as done in Figure 3, the

Table 5.5 Number of identified bird specimens and number of unidentified bird fragments from the PBO–EBO, MBO, and MAT. *Possibly a common murre as well.

	PBO-EBO	**MBO**	**MAT**
Razorbill (*Alca torda*)	1	2	1
Black guillemot (*Cepphus grylle*)	1		
Great auk (*Pinguinus impennis*)	18	21	5
Common murre (*Uria aalge*)	14	6	1
Thick-billed murre (*Uria lomvia*)*	1		
Anatidae	3		
Common goldeneye (*Bucephala clangula*)	1		
Whooper swan (*Cygnus cygnus*)	1		
Long-tailed duck (*Clangula hyemalis*)	1		1
Velvet scoter (*Melanitta fusca*)	8	4	1
Common scoter (*Melanitta nigra*)	2		
Common eider (*Somateria mollissima*)	7	3	
Great crested grebe (*Podiceps cristatus*)	3	1	
Black-throated loon (*Gavia arctica*)	3		1
Red-throated loon (*Gavia stellata*)	3		2
European herring gull (*Larus argentatus*)	3	4	
Common gull (*Larus canus*)			2
Great black-backed gull (*Larus marinus*)	3		
Manx shearwater (*Puffinus puffinus*)		1	
Great cormorant (*Phalacrocorax carbo*)	4	4	
Red-breasted merganser (*Mergus serrator*)			1
White-tailed eagle (*Haliaeetus albicilla*)		3	
Eurasian nuthatch (*Sitta europaea*)		1	
Sum of identified birds	77	50	15
Unidentified birds (Aves)	103	417	183
Total bird fragments	**180**	**467**	**198**

importance of fish becomes apparent. Even if the results from the other sites are extremely partial because of the taphonomic factors involved, the shortage of fish in their bone material does not diminish the apparent dependency on fish of the people living at Huseby Klev. Because of the inconsistency in the analysis of the fish bones so far, it serves no purpose to study the element distribution in this paper. For now, it appears as if complete fish carcasses are represented in the material, but no distributional pattern can be discerned, although this could change once the material has been fully analyzed.

The cod family dominates the assemblage, and the different species within this family typically live in water depths from 10 to 400 m (Kullander *et al.* 2012), making them available close to the shore. However, ling and especially hake normally live at somewhat greater depths and are therefore harder to catch, implying the use of longer fishing lines or seine nets (Pickard

Table 5.6 Number of identified fish specimens. The fish were selected randomly for analysis and represent 66% of the total amount of fish bone from the PBO–EBO and 5% each from the MBO and MAT.

Order	**Family**	**Species**	**PBO-EBO**	**MBO**	**MAT**
Clupeiformes	Clupeidae	Herring *(Clupea harengus)*		157	
Gadiformes	Gadidae				3
Gadiformes	Merlucciidae	European hake *(Merluccius merluccius)*	5		
Gadiformes	Lotidae	Ling *(Molva molva)*		95	2
Gadiformes	Gadidae	Cod *(Gadus morhua)*	210	110	266
Gadiformes	Gadidae	Haddock *(Melanogrammus aeglefinus)*		1	31
Gadiformes	Gadidae	Whiting *(Merlangius merlangus)*	1	3	7
Gadiformes	Gadidae	Pollock *(Pollachius virens/pollachius)*	5	49	163
Scorpaeniformes	Triglidae	Gray gurnard *(Eutrigla gurnardus)*		2	2
Perciformes	Labridae	Ballan wrasse *(Labrus bergylta)*		1	
Perciformes	Scombridae	Atlantic mackerel *(Scomber scombrus)*	7	1	
Pleuronectiformes	Pleuronectidae	Flounders (Pleuronectidae)		1	3
Pleuronectiformes	Pleuronectidae	European plaice *(Pleuronectes platessa)*	11	31	17
Rajiformes	Rajidae	Thornback ray *(Raja clavata)*		8	
Squaliformes	Squalidae	Spurdog *(Squalus acanthias)*	29	113	2
		Total NISP	**268**	**572**	**496**

and Bonsall 2004) and the use of boats to travel further off shore. The presence of herring during the MBO phase also implies the use of nets, necessary in order to catch large numbers of this species. It is also likely that herring fishing concentrated on times when the herring were gathered in large schools closer to shore for spawning. Altogether, the abundance of fish and the varied fish species found in the different phases of Huseby Klev indicate a highly specialized fishing community, especially in the two later phases.

Discussion

The site of Huseby Klev is unique and interesting in many ways, first in being the earliest known settlement on the European west coast with a sufficient amount of organic material preserved to study the diet and subsistence strategies of the pioneer settlers on the coast of the Scandinavian Peninsula. Second, the location was used and reused over a period of about two millennia, providing us with an invaluable insight into the functional and chronological changes in both the environment and culture.

The earliest evidence of human occupation along the whole stretch of western Scandinavia is dominated by coastal sites from the area around Gothenburg up to the most northern parts of Norway (Bang-Andersen 2012; Breivik 2014; Svendsen 2018). The central part of Bohuslän, which is the area around the location of Huseby Klev, has even been estimated to hold 10,000 different pioneer sites (Schmitt *et al.* 2006). It is therefore no surprise that the pioneer settlers lived on marine resources, exploiting the ocean. However, the types of marine resources being exploited changed over time. The earliest known coastal site evidence from both Huseby Klev

(PBO–EBO) and Balltorp (Jonsson 2014) indicates that aquatic mammals represented between 30% and 50% of the identified specimens, making marine mammals the dominant protein source in the human diet. Over time, this tradition seems to have changed in favour of fish, as illustrated by the massive amount of fish bone found during both the MBO and MAT. These results may present an incomplete picture because of the lack of a comprehensive overview of how much of each context was sieved with a fine mesh (1 mm). However, all the excavated earth was uniformly sieved with a 5 mm mesh sieve, and additional soil samples were selected from all three phases, so the lack of a comprehensive overview should not affect the main trends. Fluvial dispersion of smaller and lighter fish bones may have affected the trend, if this was more common in the PBO–EBO phase. According to Leif Jonsson (2005), some of the material in the earliest phase was deposited in water and some was derived from a redeposited terrestrial layer that had been washed out by the waves. This interpretation is mainly derived from finds of human bones mixed with the animal bones. However, the occurrence of human bones in refuse layers is common throughout the entire Mesolithic period, and finds of human bones in cultural layers have been documented on numerous sites, where no explanation other than cultural practice can be offered. Three decades ago, these human bone inclusions among the animal bone waste were recorded from about 37% of all Mesolithic sites with preserved bone material (Larsson *et al.* 1981). This pattern has continued with more recently excavated Mesolithic sites (Boethius 2016a; Eriksson and Magnell 2001b; Sjögren and Ahlström 2016), and calculations today indicate an even higher presence, of around 50%–70%, depending on how the calculations are made and what types of settlements are included. This is not an exclusively Scandinavian phenomenon, and the same cultural practice can be seen all over Mesolithic Europe (Newell *et al.* 1979). Study of this practice has received a new focus with finds of impaled human skulls at Motala, Sweden (Hallgren 2011), and the overrepresentation of skull fragments in Mesolithic contexts has even raised the question of a possible Mesolithic skull cult (Schulting 2015). It is therefore likely that the inclusion of human bone at Huseby Klev is part of a similar cultural practice and not the result of redeposition of a terrestrial layer with washed-out human graves.

The many examples of anatomical complexes of cod and ling heads and articulated vertebrae from gadids and white-beaked dolphins (Nordqvist 2005, 37 f.) further indicate that water movement was limited. Comparison of the number of identified mammal and bird fragments with fluvial abrasion marks (fish bones cannot be used because of their size and frailty) between the different occupations appears to indicate that fluvial marks are slightly more common in the PBO–EBO phase (24%) compared with the MAT (16%) and only half as common as in the MBO (41%), from which there are plenty of small herring finds. Further analysis and sieving of macro-samples collected from each context have the potential to illuminate this matter further; however, based on current evidence it is unlikely that fluvial sorting removed the smaller fish bones from the PBO–EBO to a greater extent than in the later occupation phases. It is therefore most likely that the observed trends are accurate and that marine fishing was of lesser importance during the transition from the Preboreal to the Boreal chronozone, with a dramatic increase over time.

This is an important observation and establishes the pioneer settlers of Northern Europe as mainly marine-mammal hunters, at least during some parts of the year. If this notion is expanded further and the results compared with studies from earlier sites in Southern Europe, the pattern observed at Huseby Klev may be explained. However, because of the limited number of older available archaeological bone assemblages, it is more difficult to study subsistence strategies further back in time. The issues of seasonality, and the different types of subsistence strategies used during different seasons of the year, along with the lack of preserved marine seashores, because of the massive transgression following the melting of the ice sheet after the last ice age, complicates the matter further. If you add unsatisfactory excavation techniques and the lack of sieving with mesh sizes less than 3 mm, and the fragile and easily perishable nature of fish bones, you are in a predicament when studying Palaeolithic subsistence. Previous models of pioneer settlers in Scandinavia have revolved around reindeer hunters (Bang-Andersen 1996; Bjerck 1994; Fuglestvedt 2003), abandoning that mode of subsistence to exploit the newly available marine environments in north-western Scandinavia (Kindgren 1996). However, many of the models forget to take both marine and freshwater systems into account as well as the seasonal and opportunistic adaptations of foraging peoples.

The main component of the ethnographic northern forager diet comes from fish, with an increasing fish dependency with increasing latitude (Cordain *et al.* 2000; Marlowe 2005). Bearing in mind that the climate prior to the Huseby Klev settlement would have made the conditions more “northern” compared with today, you would expect an even higher fish dependency than that observed in modern foraging populations at the same latitude. Furthermore, the landscape during the late ice age was dramatically different from that of today. The huge landmasses made available when the water was trapped in the ice sheet benefitted populations of freshwater-living fish species; the vast landmasses available on the ancient Doggerland were covered with freshwater estuaries and rivers (Coles 2000), with a large freshwater lake in the centre (Gaffney *et al.* 2007). Furthermore, marine fish would also have been widely available along the extensive coastline areas, which are now underwater, offering marine subsistence possibilities. Therefore, as human groups moved though the landscape, fish would always have been a resource that could be relied on in the same manner as terrestrial mammals. Interestingly, an increasing freshwater dependency can be seen in humans from the Middle Upper Palaeolithic through stable isotope analysis of $\delta^{15}N$ and $\delta^{13}C$ (Richards *et al.* 2001). This corresponds to the increasing freshwater dependency of humans suggested by the broad-spectrum revolution model (Stiner 2001), with the incorporation of small game, birds, shellfish, and fish into the diet. Unfortunately, there are few Pleistocene archaeological sites available that have been excavated in a way that would allow the small freshwater fish to be recovered (basically none where marine fish could have been found, due to the transgression) and fewer still that are preserved well enough for any fish bones to be left, because of the particular circumstances required for fish to be preserved and recovered (Boethius 2018). Examples from the Late Upper Palaeolithic cave sites of Geissenklösterle and Hohe Fels in south-western Germany include bones from Danube salmon (*Hucho hucho*), grayling (*Thymallus thymallus*), and burbot (*Lota lota*) (Conard *et al.* 2013; Hahn 2000), and finds from the Fucino basin area in Italy indicate that freshwater trout (*Salmo trutta*) was exploited by human populations in the Late Upper Palaeolithic (Russ and Jones 2009). Furthermore, bones from a number of fish species, including grayling, burbot, trout, bullhead (*Cottus gobio*), Danube salmon, chub (*Squalius cephalus*), barbell (*Barbus barbus*), common nase (*Chondrostoma nasus*), char (*Salvelinus alpinus*), pike (*Esox lucius*), roach (*Rutilus rutilus*), Eurasian minnow (*Phoxinus phoxinus*), perch (*Perca fluviatilis*), and whitefish (*Coregonus sp.*), have been found in various frequencies on another 26 Late Upper Palaeolithic sites across Central Europe (Cziesla 2004). This is a clear indication that fishing was known from the Late Upper Palaeolithic onwards, even if none of the material in question has been excavated and preserved in a way that can be used to establish how important these aquatic resources were in the human diet.

The likelihood of finding other types of evidence for Palaeolithic marine fishing is slim due to the transgression. Unfortunately, corresponding evidence of freshwater fishing practices, which would further an assessment of the importance of aquatic resources, is also limited because of the fishing practices themselves, as it is most likely that people used wooden fish traps to catch the fish, and such organic remains are less likely to be preserved than the fish bones. One possible way to circumvent this large taphonomic problem would be to identify extensive woodworking from flint wear patterns. This requires the analysis of a large proportion of many types of flint debris and artefacts from a site, which is time-consuming and expensive. However, this has been carried out recently at a Late Palaeolithic site in Blekinge, eastern Sweden, and the results indicate that a large proportion of the flint was used for woodworking (Björk *et al.* 2015). Because of the site's location on a small island in the Blekinge archipelago, this could be seen as an indirect indicator of fish trap construction.

Fishhooks could also be an indicator of fishing activity, especially in marine environments, as observed at Huseby Klev, where quantities of fishhooks (both complete and in various stages of construction) have been found (Nordqvist 2005). However, freshwater fish are relatively easy to catch with traps, and it is therefore possible that even where freshwater fish were exploited, fishhooks were not frequently used on inland fishing sites. This is illustrated at Sunnansund, where hundreds of thousands of fish bones from tonnes of fish have been recovered (Boethius 2018) with no evidence of any fish traps and just one recovered fishhook. Nevertheless, the earliest evidence of fishhooks appears during the Late Upper Palaeolithic period (Gramsch *et al.* 2013), at about the same time as the first evidence of both freshwater and marine fish bone appears in zooarchaeological material. This can be seen as further evidence of the broad spectrum revolution taking place in the Late Upper Palaeolithic, where fish become increasingly important. Marine fish have also been found on Late Palaeolithic sites which, due to their location by the Mediterranean Sea, have not been similarly affected by the transgression. Research from the Nerja Caves in southern Spain shows that marine fish appear in greater numbers in bone assemblages from about 12,500 BP onwards (Aura *et al.* 2002, Table 5.3). Furthermore, indications from the Franchti Cave in Greece indicate that from around 11,000 cal BP humans were catching fast-swimming pelagic fishes such as Atlantic bluefin tuna (*Thunnus thynnus*) (Stiner and Munro 2011), implying a sophisticated knowledge of both fishing and watercraft.

Even though the majority of these aquatic indicators are remote from a Huseby Klev perspective, the body of evidence indicates that aquatic resources had been exploited by humans for millennia prior to the Huseby Klev occupation. Moreover, the evidence indicates that humans were well aware of how to exploit aquatic habitats and that people had long been in contact with different types of aquatic resources.

In readdressing the issue of pioneer subsistence models and the reason why aquatic mammals dominate the diet in the earliest phase of Huseby Klev, I suggest an alternative to the abandonment of reindeer hunting proposed by Kindgren (1996). In light of current evidence, the marine-mammal-dominated diet of the Scandinavian pioneers can be seen as a continuous adaptation of the well-known exploitation of aquatic resources. As the ice sheet retracted further north at the end of the ice age, a zone of very high bioproductivity appeared in the North Sea. This conclusion is drawn from modern observations of ice edge zones, which form some of the most bioproductive places on earth, where large amounts of primary phytoplankton support an elevated number of higher-trophic-level species, including a concentration of top predators such as whales and seals (Smith and Nelson 1985). Furthermore, analyses of 500,000 years of sediment records from Antarctica indicate reoccurring bioproductive booms during glacial melts, which have been interpreted as the result of glacial meltwater bringing terrestrial nutrition into the ocean, to the benefit of primary phytoplankton (Flores *et al.* 2012). The observed patterns from Antarctica and modern-day high levels of biomass around ice edges are likely to be general phenomena and were therefore also present as the ice melted in Northern Europe in the early Holocene. The steady and continuous flow of freshwater created an ideal environment for phytoplankton growth, because the introduction of freshwater reduces the density of surface water, which allows for vertical stability with the possibility of a more illuminated area, favouring the phytoplankton (Smith and Nelson 1986). By adding the large freshwater outlet from the Vänern basin, which brought even more nutrition into the ocean (Kindgren 1995), and the nutritional level needed to create the large shell banks observed on the coast of Bohuslän from the end of the ice age, you get an extremely nutritious ocean on the west coast of Sweden during the beginning of Holocene, with optimal conditions for marine life prevailing for hundreds of years, centred around 10,500 BP (Fredén 1986, 1988). The ocean experienced an ecological bonanza and was therefore able to support an abundant and flourishing marine fauna, which made it possible for whales and seals to thrive in the area. Marine mammals were consequently more abundant prior to and overlapping with the initial phase of Huseby Klev, because of the larger primary biomass in the ocean.

As the ice sheet disappeared biomass production in the ocean decreased, which led to fewer marine top predators. Furthermore, a strong tradition of marine-mammal hunting during the peak of oceanic biomass production probably continued into less advantageous circumstances, with less food available for the whales, which might have led to overexploitation. This is supported by the numerous sites that have been found in the area, where the oldest sites are located primarily in narrow straits, whereas the younger sites are spread across many types of habitat (Kindgren 1995, 181), implying a diversification of resources. In fact the topographic information (Figure 5.10) shows that Huseby Klev was located in one such strait during the initial phase and that the strait had disappeared during the later phases, having become a bay instead. This indicates changing requirements for catching white-beaked dolphin and porpoise; for example, the traditional methods of catching small whales from the Faroe Islands and Japan is to herd them into bays or small straits to be killed with hand-held weapons (Bloch *et al.* 1990; Reeves 2009). During the Early Preboreal chronozone the pioneer settlers experienced a bonanza, with an abundance of whales and seals, and located their settlements at the ends of narrow straits, where they could easily attack their prey while it was swimming

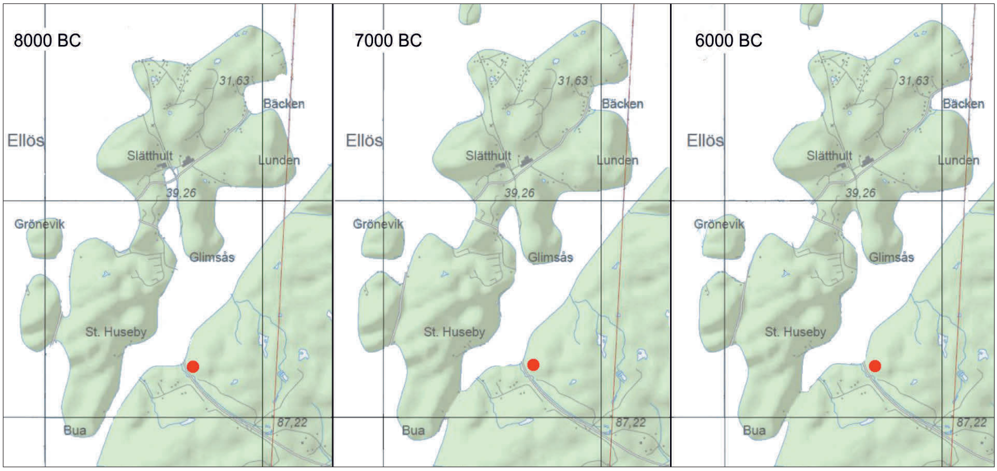

Figure 5.10 Topographic map showing Huseby Klev during the three different occupation phases: PBO–EBO at 10,000 cal BP, MBO at 9000 cal BP, and MAT at 8000 cal BP. Notice the open strait in the southern part of the map during the PBO–EBO phase. The map is based on terrain models using topographic information from the Swedish Geological Survey (© SGU).

through. The open straits would possibly allow the dolphins to feel safe, if herded by humans in boats, as they use biosonar echolocation when navigating through the water (Madsen and Surlykke 2014). This enables dolphins to "map" the underwater landscape and thereby avoid the enclosure of a bay, something they are not able to do when confronted with modern motorboats, able to move faster than themselves, whereby bays can be used to entrap dolphins by modern whalers but not by prehistoric ones.

As time went by it became harder to hunt the marine mammals, and during the later stages people needed to exploit different types of habitat or follow the coastline further north to maintain a lifestyle supported by the same marine resources. The people who occupied the same area after the decrease in primary biomass production are consequently found occupying many different habitats, exploiting a broad spectrum of marine resources. The naturally diminishing small-whale population in combination with a large number of people living in the area (as observed by the abundance of settlements) and the pattern of marine-mammal dominance in the diet in the PBO–EBO phase (indicating possible overexploitation) probably led to a collapse of the marine-mammal population. This, in turn, led to a change in the subsistence strategies, and fish came to dominate the diet. The first phase of occupation at Huseby Klev occurred at the end of the pioneer era, when marine mammals still dominated the diet. The topographic information and zooarchaeological evidence agree on an interpretation of a shift in dietary focus. Taking into account the abundance of fish in the later stages of Huseby Klev, combined with the landscape topography, it is possible to extrapolate the results from Huseby Klev to sites where no organic material is available. Huseby Klev is therefore key to unlocking the subsistence strategies of the people who populated sites deprived of organic material for taphonomic reasons.

Along with the change of focus on the marine resources from a larger reliance on marine mammals to a higher dependency on fish, there is also a shift in the exploitation of terrestrial mammals. In the first phase of Huseby Klev wild boar dominate the ungulate material, representing more than 60% of the identified ungulates. This initial dominance of wild boar should be viewed in the context of this species's colonization abilities: the fast reproductive capacity of wild boar enables it to populate the landscape faster than other ungulates. While wild boar is still an important terrestrial resource during the MBO and MAT, roe deer is more abundant and becomes increasingly important over time. Red deer appears to be of roughly equal importance throughout the occupation phases, with a slight dip in the MBO. All of this evidence is in concordance with the increasing abundance of roe deer over time on coastal sites throughout the Scandinavian Mesolithic, with red deer displaying a wider frequency and a trend of being more common on inland than on coastal sites (Magnell forthcoming, a). The lack of aurochs and the low frequency of elk in the assemblage is considered to be a reflection of the location of Huseby Klev and the Schlepp effect, i.e., that it is hard to transport the bones of large ungulates back to camp. The large landmasses available in the east would have provided an optimal habitat for large ungulates, and it is plausible that the largest ungulates were hunted there, the bones remaining at mainland camps, and only the meat being brought back to the island settlements. The element distribution of the ungulate species that were found on Huseby Klev suggests a shift in utilization of the bodies. Evidence from the PBO–EBO indicates that large proportions of the ungulate bodies were brought back to the settlement, while the element distribution in the MBO and MAT indicates a more selective approach. This pattern could be a result of the observed shift in subsistence strategies, because different tools would have been needed to hunt marine mammals compared to fishing, resulting in the need to acquire different body parts to construct a different toolkit.

Even though bones that could be used for age estimation were scarce in the material, it is possible to observe a few trends that have implications for understanding the terrestrial hunting strategies. Wild boar seems to have been hunted from a young age. However, only a relatively small outtake of young individuals occurred during the PBO–EBO phase. The outtake of young wild boar nearly doubled during the MBO phase, when no apparent age selection seems to have been applied. Compared with the trend of hunting all ages of wild boar, red deer seem to have been more conservatively hunted, although the low sample size complicates the interpretation. It was only possible to study an age trend for roe deer age during the MAT, and the results suggest a hunting strategy similar to that of the wild boar, with a small outtake of younger animals and a focus on older individuals. These patterns have been observed in other contemporaneous contexts, where wild boar of all ages has been hunted and roe deer was hunted somewhat more flexibly, with some sites displaying young animals and others not. The common trend in red deer hunting is that young individuals are lacking in assemblages (Boethius 2017; Eriksson and Magnell 2001b). This is possibly because of their slower reproductive cycle; if red deer are hunted at a young age, it takes longer for the next generation of young to replace the population compared with the young of wild boar and roe deer. This makes it more advantageous to hunt red deer after they have matured and reached full body size, enabling a maximum return in terms of meat gain and, more importantly, as red deer bones are often the most commonly used bones for toolmaking (Boethius 2016a; Leduc 2012), it would allow the bones to grow as large as possible and harden after they have finished growing.

Another interesting aspect of ungulate hunting is the presence of reindeer in the material. Reindeer has never been found in an archaeological context from the Mesolithic west coast of Scandinavia. Even though reindeer are frequently found in both Scania in Sweden and in Denmark from the Late Glacial into the Preboreal chronozone, there has not been a general consensus on where the reindeer went after this and whether they were present on the west coast, even though reindeer has been found in geological subfossil contexts from Middle Sweden (Nybelin 1943) and recently in archaeological contexts from Dalarna in Middle Sweden (Ekholm 2014). However, regarding the reindeer finds from the PBO–EBO at Huseby Klev, it is likely that reindeer was present on the west coast during the Early Mesolithic and that the species probably migrated from the south as the climate grew warmer, because reindeer suffers from heat stress if temperatures rise above 15°C (Johnsen and Mercer 1993). Interestingly, all the reindeer from Scania and Denmark are subfossil finds from bogs that, apart from one Danish find (Holm 1992), are not associated with human settlements (Aaris-Sørensen *et al.* 2007; Larsson 2012; Liljegren and Ekström 1996). However, there are cut and chop marks on many of the reindeer bones from southern Scandinavia, which implies that reindeer were hunted (Larsson 2012). However, because there are so few available Late Glacial and Preboreal sites with preserved bone material, these bog finds of reindeer might represent the remains of opportunistic reindeer hunts. There is no evidence of a more organized and dedicated reindeer-hunting practice, which would probably have occurred during the annual migrations, resembling that of the well-known reindeer kill sites at Meiendorf and Stellmoor in northern Germany (Rust and Gripp 1937; Rust 1943). It has also been suggested that reindeer was mainly hunted during migrations in the spring and autumn (Aaris-Sørensen *et al.* 2007). The lack of reindeer bones at the contemporaneous Almeö inland site (Arnesson-Westerdahl 1984) could also be seen in this context, and their absence could be viewed as an indication that seasonal hunting was taking place elsewhere, implying a low dependency on reindeer for general subsistence. Therefore, the lack of reindeer bones in previously analysed archaeological sites, the stray finds in bogs, and the reindeer bones found at Huseby Klev most probably indicate that the Scandinavian pioneers did not follow reindeer herds as a major part of their subsistence strategy but instead exploited reindeer opportunistically and probably on their annual routes through the landscape during the migrations. This left the humans with the aquatic resources, birds, and other terrestrial mammals as sustenance for most of the year.

Indeed, study of the isotope signals from the bones of Early Mesolithic humans from Scandinavia makes it even more obvious that there was no general reindeer-based economy. The oldest known individual humans from Scandinavia display a large variation in their diet, generally corresponding to their location in the landscape. Four individuals from Huseby Klev (bones removed prior to this analysis) have been analysed, and they display typical marine signals (Eriksson 2003), corresponding well with a large input of marine mammals or large higher-trophic-level fish. About 20 and 30 km, respectively, to the north of Huseby Klev the skeleton of a woman from Österöd and the skull of a man from Skibevall have been found (Sjögren and Ahlström 2016). The Österöd woman is contemporary with the PBO–EBO phase, and the Skibevall man with the MBO phase. Both individuals display elevated δ15N values but more terrestrial δ13C values, implying a larger input of freshwater fish in the diet. The earliest Scandinavian inland sites with known human isotope signals come from Koelbjerg, Tømmerupgårds Mose, Hedegård, Holmegård V, Mullerup I, Hanaskede, Bredgården, Ageröd I:HC, Malmö harbour, and Sunnansund (Boethius and Ahlström, submitted; Borrman *et al.*; Eriksson 2003; Fischer *et al.* 2007; Sjögren and Ahlström 2016). The isotope signals vary between the different samples, but the general trend is a more inland-dominated diet. Unfortunately, it is difficult to say if the inland signals are terrestrial or aquatic, due to the many problems associated with δ13C and δ15N isotope values in freshwater fish (for further discussion see Boethius 2018).

Other important results from the Huseby Klev material come from the frequently occurring bird bones. Birds were hunted throughout the settlement phases at Huseby Klev. Although the bird bones warrant closer analysis to evaluate their importance as a subsistence source, currently they indicate a general opportunistic hunting approach, with a large number of species represented by a few identified fragments from each species. The exception to this trend is the hunting of auks, which appear to have been hunted in an organized manner, generating a large amount of identified fragments from a greater number of individuals. The most common bird in all three phases of the Huseby Klev occupation is the now-extinct great auk, which was a large water-living flightless bird, weighing up to 5 kg. The large number of finds of great auk at Huseby Klev follows a coastal trend; the great auk is frequently found in deposits from coastal settings in Italy during the Late Pleistocene, and there are numerous finds along the Norwegian west coast in both kitchen middens and subfossil postglacial deposits (Bengtson 1984). This implies a high dietary importance and also that the great auk had a large impact on many prehistoric cultures. This interpretation is further enhanced by numerous accounts from North America, where the great auk is often found in foraging societal contexts, both as food waste and in ritual contexts (Crofford 1989; Tuck 1976). The numerous finds of great auk at Huseby Klev might also imply a nearby nesting area, where the birds gathered to lay eggs, making them an easy target. Commonly, they did so on unpopulated islands, where they were safe from predation, although it may have been possible to catch them with the help of boats, driving the birds ashore, where they could then be easily caught (Bengtson 1984), implying a similar hunting strategy to that used for whales. This, along with indications of the driving of small whales and the finds of pelagic and deeper-sea fish, implies the use of sturdy and functional boats to travel on and forage from the ocean. Most of the bird species are also marine, which further enhances the picture of a society that based its subsistence strategies on the aquatic environment.

Similar to the birds, apart from the auks, fur game seems to have been opportunistically hunted. Even though some species, such as fox, otter, and water vole, were common or present throughout all phases, no other uniformity between the different occupation phases was obvious. Some consistency in element distribution could be seen for the beaver, of which only skull fragments were present. Water vole was also most commonly represented by skull fragments; however, this is probably a taphonomic issue, as teeth are more easily preserved and determinable for rodents. Apart from this, no other trends could be detected in the element distribution. The large variety of fur game, from large bears and wolves to small squirrels and pine martens, suggests that different hunting strategies were probably used. The fur game bone material suggests ever-present but low-intensity hunting, which corresponds to the idea of fur game being hunted for pelts rather than meat. The hunting of fur game at Huseby Klev therefore reflects the same approach taken with the other animal groups: the terrestrial species are primarily sought for raw material other than food, while the aquatic species fulfil the general dietary needs.

Conclusions

The results of the analysis of the bone material from the three different Mesolithic phases of Huseby Klev have to take centre stage in the debate regarding the Scandinavian pioneer settlers and the change in subsistence strategies during the following millennia. The results show that the pioneer settlers were initially highly dependent on marine mammals for their subsistence, and that a subsequent marine-mammal population collapse, induced by human overexploitation of a marine-mammal population in decline, resulted in an increasing reliance on fish. The bone material indicates a heavy reliance on the aquatic environment throughout all three phases, with fish, marine mammals, and marine birds providing the basis for human sustenance. The terrestrial species are seen as secondary providers, hunted to provide raw materials and complement the diet rather than being an invaluable source of nutrition.

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References

Aaris-Sørensen, K. 1976. “A zoological investigation of the bone material from Sværdborg I–1943.” *Arkæologiske Stud* 3: 137–148.

Aaris-Sørensen, K., R. Mühldorff and E. B. Petersen. 2007. “The Scandinavian reindeer (*Rangifer tarandus L.*) after the last glacial maximum: Time, seasonality and human exploitation.” *Journal of Archaeological Science* 34: 914–923.

Arnesson-Westerdahl, A. 1984. *Den tidigmesolitiska faunan vid Hornborgasjön, Västergötland. Osteologisk analys av djurbensmaterialet från 1983 års arkeologiska undersökningar på Almeö 96 B.* Unpublished report.

Aura Tortosa, J. E., J. F Jordá Pardo, M. Pérez Ripoll, M. J. Rodrigo García, E. Badal García and P. Guillem Calatayud. 2002. “The far south: The Pleistocene–Holocene transition in Nerja Cave (Andalucıa, Spain).” *Quaternary International* 93: 19–30.

Bang-Andersen, S. 1996. “Coast/inland relations in the Mesolithic of southern Norway.” *World Archaeology* 27(3): 427–443.

———. 2012. “Colonizing contrasting landscapes: The pioneer coast settlement and inland utilization in southern Norway 10,000–9500 years before present.” *Oxford Journal of Archaeology* 31 (2): 103–120.

Bengtson, S-A. 1984. “Breeding ecology and extinction of the Great Auk (Pinguinus impennis): anecdotal evidence and conjectures.” *The Auk* 101: 1–12.

Binford, L. R. 1978. *Nunamiut Ethnoarchaeology*. New York: Academic Press.

———. 1981. *Bones: Ancient Men and Modern Myths.* New York: Academic Press.

Bjerck, H. B. 1994. “Nordsjøfastlandet og pionerbosetningen i Norge.” *Viking* 57: 25–58.

Björk, T., B. Knarrström and C. Persson. 2015. “Damm 6 och Bro 597. Boplatslämningar och en hydda från tidigmesolitikum. Särskild arkeologisk undersökning 2011 och arkeologisk förundersökning 2012. Ysane socken, Sölvesborgs kommun i Blekinge län.” *Blekinge museum rapport* 2014:14.

Bloch, D., G. Desportes, K. Hoydal, P. Jean. 1990. “Pilot whaling in the Faroe Islands, July 1986–July 1988.” *North Atlantic Studies* 2: 2.

Boethius, A. 2016a. “Osteologiska analyser av det mesolitiska materialet.” In “Norje Sunnansund. Boplatslämningar från tidigmesolitikum och järnålder. Särskild arkeologisk undersökning 2011 och arkeologisk förundersökning 2011 och 2012, Ysane socken, Sölvesborgs kommun.” *Blekinge museum rapport* 2014,10, edited by M. Kjällquist, A. Emilsson and A. Boethius, 145–232. Karlskrona: SHMM arkeologerna.

———. 2016b. “Something rotten in Scandinavia: The world’s earliest evidence of fermentation.” *Journal of Archaeological Science* 66: 169–180.

———. 2017. “Signals of sedentism: The use of the environment as evidence of a delayed-return economy in Early Mesolithic south eastern Sweden.” *Quaternary Science Reviews* 162: 145–168

———. 2018. “The use of aquatic resources by Early Mesolithic south Scandinavian foragers.” In *The Early Settlement of Northern Europe: Transmission of Knowledge and Culture,* edited by K. Knutsson, H. Knutsson, J. Apel and H. Glørstad, 311–334. The Early Settlement of Northern Europe, volume 2. Sheffield: Equinox Publishing.

Boethius, A. and T. Ahlström. Submitted. “Fish and resilience among early Holocene foragers of southern Scandinavia: a fusion of stable isotopes and zooarchaeology through Bayesian mixing modelling.” *Journal of Archaeological Science.*

Borrman, Helene, E. Urban Engström, Verner Alexandersen, Leif Jonsson, Anna-Lena Gerdin, and Gunnar E. Carlsson. 1996. “Dental conditions and temperomandibular joints in an early Mesolithic bog man.” *Swedish Dental Journal* 20: 1–14.

Bosold, K. 1966. *Geschlechts-und Gattungsunterschiede an Metapodien und Phalangen mitteleuropäischer Wildwiederkäuer.* München.

Breivik, H. M. 2014. “Palaeo-oceanographic development and human adaptive strategies in the Pleistocene–Holocene transition: A study from the Norwegian coast.” *The Holocene* 24(11): 1478–1490.

Broholm, H., K. Jessen and H. Winge. 1924. “Nye fund fra den ældste stenalder. Homegaard- og Sværdborgfundene.” *Aarbøger for nordisk oldkyndighed og historie*. Copenhagen.

Bull, G. and S. Payne. 1982. “Tooth eruption and epiphysial fusion in pigs and wild boar.” In *Ageing and Sexing Animal Bones from Archaeological Sites*, edited by B. Wilson, C. Grigson and S. Payne, 55–71. British Archaeological Reports 109. Oxford: British Archaeological Reports.

Christensson, V. 2015. “Vilt i området kring kustboplatsen Huseby Klev, En analys av vilt som påträffats i det osteologiska materialet inom Huseby Klev från tidigmesolititkum.” *Seminar paper in Historical Osteology.* Lund: Department of Archaeology and Ancient History, Lund University.

Coles, B. J. 2000. “Doggerland: The cultural dynamics of a shifting coastline.” *Geological Society, London, Special Publications* 175: 393–401.

Conard, N. J., K. Kitagawa, P. Krönneck, M. Böhme and S. C. Münzel. 2013. “The importance of fish, fowl and small mammals in the Paleolithic diet of the Swabian Jura, Southwestern Germany: In *Zooarchaeology and Modern Human Origins: Human Hunting Behavior during the Later Pleistocene*, edited by J. L. Clark and J. D. Speth, 173–190. Vertebrate Paleobiology and Paleoanthropology. Dodrecht: Springer.

Cordain, L., J. B. Miller, S. Eaton, N. Mann, S.H.A. Holt and J. D Speth. 2000. "Plant-animal subsistence ratios and macronutrient energy estimations in worldwide hunter-gatherer diets." *The American Journal of Clinical Nutrition* 71(3): 682–692.

Costa, A.P.B. and P. C. Simões-Lopes. 2012. "Physical maturity of the vertebral column of Tursiops truncatus (Cetacea) from Southern Brazil." *Neotropical Biology and Conservation* 7: 2–7.

Crofford, E. 1989. *Gone forever: The Great Auk*. New York: Crestwood House.

Cziesla, E., 2004. "Late Upper Palaeolithic and Mesolithic cultural continuity—or: Bone and antler objects from the Havelland." In *Hunters in a Changing World*, edited by Th. Terberger & V. Eriksen, 165–182. Internationale Archäologie 6. Rahden: Verlag Marie Leidorf.

Ekholm, T. 2014. "Osteologisk analys." In *Pionjärerna vid Limsjön. Arkeologisk undersökning av boplats från äldre stenålder, RAÄ 405 i Leksands socken och kommun, Dalarna*, edited by J. Wehlin, 83–86. Falun: Dalarnas museum.

Enghoff, I. B. 2007. "Viking age fishing in Denmark, with particular focus on the freshwater site Viborg, methods of excavation and smelt fishing." In *International Council for Archaeozoology. Fish Remains Working Group. Meeting (2007). The role of fish in ancient time: proceedings of the 13th meeting of the ICAZ Fish Remains Working Group in October 4th-9th, Basel/Augst 2005*, edited by H. H. Plogmann, 69–76. Rahden: Verlag Marie Leidorf.

Eriksson, G. 2003. *Norm and difference: Stone Age dietary practice in the Baltic region.* Stockholm: Jannes Snabbtryck Kuvertproffset HB

Eriksson, M. and O. Magnell. 2001a. "Det djuriska Tågerup. Nya rön kring Kongemose-och Erteböllekulturens jakt och fiske." In *Tågerup. Specialstudier,* edited by P. Karsten and B. Knarrström, 156–237. Lund: Riksantikvarieämbetet UV Syd, Avd. för arkeologiska undersökningar.

———. 2001b. "Jakt och slakt." In *Dansarna från Bökeberg. Om jakt, ritualer och inlandsbosättning vid jägarstenålderns slut*, edited by P. Karsten, 48–77. Stockholm: Riksantikvarieämbetets förl.

Fischer, A., J. Olsen, M. Richards, J. Heinemeier, A. E. Sveinbjornsdottir and P. Bennike. 2007. "Coast–inland mobility and diet in the Danish Mesolithic and Neolithic: Evidence from stable isotope values of humans and dogs." *Journal of Archaeological Science* 34: 2125–2150.

Flores, J.-A., G. M. Filippelli, F. J. Sierro and J. Latimer. 2012. "The 'White Ocean' hypothesis: a late pleistocene southern ocean governed by coccolithophores and driven by phosphorus." *Frontiers in microbiology* 3: 1–13.

Fredén, C. 1986. *Quaternary Marine Shell Deposits in the Region of Uddevalla and Lake Vänern*. Uppsala: Sveriges geologiska undersökning.

———. 1988. *Marine Life and Deglaciation Chronology of the Vänern Basin, Southwestern Sweden*. Göteborg: Chalmers tekniska högskola, Göteborgs universitet, Geologiska institutionen.

Fuglestvedt, I. 2003. "Enculturating the landscape beyond Doggerland." In *Mesolithic on the Move*, edited by L. Larsson, H. Kindgren, K. Knutsson, D. Loeffler and A. Åkerlund, 103–107. Oxford: Oxbow Books.

Gaffney, V. L., K. Thomson and S. Fitch. 2007. *Mapping Doggerland: The Mesolithic Landscapes of the Southern North Sea*. Oxford: Archaeopress.

Gramsch, B., J. Beran, S. Hanik and R. S. Sommer. 2013. "A Palaeolithic fishhook made of ivory and the earliest fishhook tradition in Europe." *Journal of Archaeological Science* 40(5): 2458–2463.

Habermehl, K. 1961. *Die Altersbestimmung bei Haustieren, Pelztieren und beim jagdbaren Wild.* Berlin: Parey.

Hahn, J. 2000. "The Gravettian in southwest Germany—environment and economy." In *Hunters of the Golden Age: The mid Upper Palaeolithic of Eurasia, 30,000–20,000 BP*, edited by J. Svoboda, W. Roebroeks, M. Mussi and K. Fennema, 249–256. Leiden: University of Leiden.

Hallgren, F. 2011. “Mesolithic skull depositions at Kanaljorden, Motala, Sweden.” *Current Swedish Archaeology* 19: 244–246.

Hatting, T. 1969. “Er bæverens tænder benyttet som redskaber i stenalderen i Danmark.” *Aarbøger for Nordisk Oldkyndighed og Historie*, 116–126. Copenhagen: Det Kongelige Nordiske Oldskrift-Selskab.

Heinrich, D. 1991. *Untersuchungen an Skelettresten wildlebender Säugetiere aus dem mittelalterlichen Schleswig: Ausgrabung Schild 1971–1975*. Neumünster: Wachholtz.

Hellgren, F. 2015. “En osteologisk analys av benmaterialet från den mesolitiska kustboplatsen Huseby Klev.” *Seminar paper in Historical Osteology*. Lund: Department of Archaeology and Ancient History, Lund University.

Holm, J. 1992. “Rensdyrjægerbopladser ved Slotseng–og et 13.000-årigt dødishul med knogler og flint.” *Nationalmuseets Arbejdsmark* 1992: 52–63.

Hultgreen, T., O. Johansen and R. Lie. 1985. “Stiurhelleren i Rana Dokumentasjon av korn, husdyr og sild i yngre steinalder.” *Viking* 48: 83–102.

Iregren, E. and J. Lepiksaar. 1993. “The Mesolithic site in Hög in a South Scandinavian perspective—A snap shot from early Kongemose culture.” *Zeitschrift für Archäologie* 27: 29–38.

Johansen, F. 1919. “En boplads fra den ældste stenalder I Sværdborg mose.” *Aarbøger for Nordisk Oldkyndighed og Historie*. Copenhagen: Det Kongelige Nordiske Oldskrift-Selskab.

Johnsen, H. and J. Mercer. 1993. “Kuldetoleranse og temperaturregulering hos rein.” *Ottar* 195: 32–37.

Jonsson, L. 1995. “Vertebrate fauna during the Mesolithic on the Swedish west coast.” In *Man and Sea in the Mesolithic: Coastal Settlement Above and Below Present Sea Level*, edited by A. Fischer, 147–160. Oxbow Monograph 53. Oxford: Oxbow Books.

———. 1996. *Fauna och landskap i Göteborgstrakten under boreal tid. Djurbensfynden från den boreala kustboplatsen vid Balltorp, Mölndals kommun, Vg*. Kungsbacka: Riksantikvarieämbetet UV Väst Rapport.

———. 2005. “Rapport over inledande osteologisk underökning.” In “Huseby Klev, en kustboplats med bevarat organiskt material från äldsta mesolitikum till järnålder, Bohuslän, Morlanda socken, Huseby 2:4 och 3:13. RAÄ 89, 485,” edited by B. Nordqvist, 96–103. *UV-väst Rapport* 2.

———. 2014. “Osteologisk analys—djurbenen från den preboreala kustboplatsen i Balltorp, RAÄ 182 i Mölndal, Västergötland.” In “En 10 000 år gammal boplats med organiskt material i Mölndal; Ytterligare en överlagrad Sandarnaboplats vid Balltorp Västra Götalands län, Västergötland, Mölndal stad, Balltorp 1:124, Mölndal 182,” edited by G. Johansson, 48–52. *UV-väst rapport* 2014: 91.

Kindgren, H. 1995. “Hensbacka-Hogen-Hornborgasjön: Early Mesolithic coastal and inland settlements in western Sweden.” In *Man and Sea in the Mesolithic: Coastal Settlement Above and Below Present Sea Level*, edited by A. Fischer, 171–184. Oxbow Monograph 53. Oxford: Oxbow Books.

———. 1996. “Reindeer or seals? Some Late Palaeolithic sites in central Bohuslän.” In *The Earliest Settlement of Scandinavia and its Relationship with Neighbouring Areas,* edited by L. Larsson, 191–205. Acta Archaeologica Lundensia. Series in 8°. Stockholm: Almqvist & Wiksell.

Kullander, S. and B. Delling. 2012. *Nationalnyckeln till Sveriges flora och fauna. [DZ 35–108], Ryggsträngsdjur: Strålfeniga fiskar : Chordata: Actinopterygii*. Uppsala: Artdatabanken, Sveriges lantbruksuniversitet.

Larsson, L. 1978. “Mesolithic antler and bone artefacts from Central Scania.” *Meddelanden från Lunds universitets historiska museum* 1977–1978: 28–67

———. 2012. “Senpaleolitiskt hornhantverk från Hassleberga, sydvästra Skåne.” *Fornvännen* 107(2): 73–79.

Larsson, L., C. Meiklejohn and R. R. Newell. 1981. “Human skeletal material from the Mesolithic site of Ageröd I: HC, Scania, Southern Sweden.” *Fornvännen* 76: 161–167.

Leduc, C. 2012. “Ungulates exploitation for subsistence and raw material, during the Maglemose culture in Denmark: The example of Mullerup site (Sarauw’s Island) in Sjælland.” *Danish Journal of Archaeology* 1: 62–81.

Lepiksaar, J. 1978. “Bone remains from the mesolithic settlements Ageröd I:B and Ageröd I:D.” In *Ageröd I:B – Ageröd I:D: A Study of Early Atlantic Settlement in Scania,* edited by L. Larsson, 186–244. Acta Archaeological Lundensia Series in 4° N° 12. Bonn: R. Habelt Verlag.

———. 1982. “Djurrester från den tidigatlantiska boplatsen vid Segebro nära Malmö i Skåne (Sydsverige).” In *Segebro. En tidigatlantisk boplats vid Sege å mynning,* edited by L. Larsson, 105–128. Malmöfynd 4. Malmö: Malmö Museum.

———. 1983a. “Animal remains from the atlantic bog site at Ageröd V in central Scania.” In *Ageröd V: An Atlantic Bog Site in Central Scania*, edited by L. Larsson, 159–168. Acta archaeologica Lundensia. Series in 8°. Lund: Lund Institute of Archaeology.

———. 1983b. “Zoologisk undersökning.” In *Bua Västergård — en 8000 år gammal kustboplats*, edited by J. Wigfors, L. Kaelas and S. Aandersson, 115–161. Gothenburg: Göteborgs arkeologiska museum.

Liljegren, R. and J. Ekström. 1996. “The terrestrial late glacial fauna in South Sweden.” *Acta Archaeologica Lundensia. Series in 8,* 135–139. Stockholm : Almquist & Wiksell.

Lupo, K. D. 2006. “What explains the carcass field processing and transport decisions of contemporary hunter-gatherers? Measures of economic anatomy and zooarchaeological skeletal part representation.” *Journal of Archaeological Method and Theory* 13: 19–66.

Lyman, R. L. 1991. *Prehistory of the Oregon Coast*. New York: Academic.

Madsen, P. T. and A. Surlykke. 2014. “Echolocation in air and water.” In *Biosonar,* edited by A. Surlykke, P. Nachtigall, R. Fay and A. Popper, 257–304. New York: Springer.

Magnell, O. 2006. *Tracking Wild Boar and Hunters: Osteology of Wild Boar in Mesolithic South Scandinavia*. Lund: Lund University.

———. 2017. “Climate change at the Holocene Thermal Maximum and its Impact on Wild Game Populations in South Scandinavia.” In *Climate Change and Human Responses*, edited by G. Monks, 123–135. Springer: Netherlands

———. forthcoming a. “Hunters in Their Environment: Mesolithic Hunting in Relation to a Changing Environment and Its Affect on Wild Game Populations in South Scandinavia.” In *MESO 2010. Proceedings of the Eight International Conference on the Mesolithic in Europe, Santander 13th–17th September, 2010.*

Marlowe, F. W. 2005. “Hunter-gatherers and human evolution.” *Evolutionary Anthropology: Issues, News, and Reviews* 14: 54–67.

Møhl, U. 1984. “Dyreknogler fra nogle af borealtidens senere bopladser i den sjællandske Aamose.” *Aarbøger for Nordisk oldkyndlighed og historia* 1984: 47–60.

Nemecek, M. 2015. “Ett Skiftade Mesolitikum En analys av artsammansättningen av klövvilt på nordiska boplatser under mesolitikum.” *Seminar paper in Historical Osteology.* Lund: Department of Archaeology and Ancient History, Lund University.

Newell, R. R., T. S. Constandse-Westermann and C. Meiklejohn. 1979. “The skeletal remains of Mesolithic man in Western Europe: An evaluative catalogue.” *Journal of Human Evolution* 8: 1–233.

Noe-Nygaard, N. 1995. *Ecological, Sedimentary and Geochemical Evolution of the Late-glacial to Post-glacial Åmose Lacustrin Bay, Denmark*. Fossils and Strata 37. Oslo: Scandinavian University Press.

Nordqvist, B. 2005. *Husby klev: en kustboplats med bevarat organiskt material från äldsta mesoliticum till järnålder: Bohuslän, Morlanda socken, Huseby 2: 4 och 3: 13, RAÄ 89 och 485: arkeologisk förundersökning och undersökning.* Mölndal: Riksantikvarieämbetet, UV Väst, Avdelningen för arkeologiska undersökningar.

Nybelin, O. 1943. “Västsvenska subfossilfynd av ren, kronhjort och uroxe.” *Göteborgs Museum. Årstryck,* 1943: 99–117.

Perkins, J. D. and P. Daly. 1968. “A hunters’ village in neolithic Turkey.” *Scientific American* 219 (5): 96–106.

Pickard, C. and C. Bonsall. 2004. “Deep-sea fishing in the European Mesolithic: Fact or fantasy?” *European Journal of Archaeology* 7(3): 273–290.

Reeves, R. 2009. “Hunting of marine mammals.” In *Encyclopedia of Marine Mammals*, edited by W. F. Perrin, B. Wursig and J. Thewissen, 585–588. Burlington: Academic Press.

Richards, M.P., P. Pettitt, M. C. Stiner, E. Trinkaus. 2001. “Stable isotope evidence for increasing dietary breadth in the European mid-Upper Paleolithic.” *Proceedings of the National Academy of Sciences* 98: 6528–6532.

Rosenlund, K. 1971. “Zoological material.” In “Sværdborg II, A Maglemose hut from Sværdborg bog, Zealand, Denmark,” edited by E. Brinch Petersen. *Acta Archaeologica* XLII: 59–62. Copenhagen.

———. 1980. “Knoglematerialet fra bopladsen Lundby II.” In *Lundbyholmen. Pladser av Maglemose-type i Sydsjælland*, edited by G. Henriksen, 128–142. Copenhagen: Det Kongelige Nordiske Oldskrift-Selskab.

Russ, H. and A. K. Jones. 2009. “Late Upper Palaeolithic fishing in the Fucino Basin, central Italy, a detailed analysis of the remains from Grotta di Pozzo.” *Environmental Archaeology* 14: 155–162.

Rust, A. 1943. *Die alt-und mittelsteinzeitlichen Funde von Stellmoor.* Utgivelselssted: Deutsches Archäologisches Institut., Neumünster: Wachholtz.

Rust, A. and K. Gripp. 1937. *Das altsteinzeitliche Rentierjägerlager Meiendorf.* Neumünster: Wachholtz.

Sarauw, G. 1903. “En stenalders boplats i Maglemose ved Mullerup, Sammenholt med beslægtede fund. Bidrag til belysning af nystenalderens begyndelse i Norden.” *Aarbøger for nordisk oldkyndighed og historie 1903.* Copenhagen: Det Kongelige Nordiske Oldskrift-Selskab.

Schmitt, L., S. Larsson, C. Schrum, I. Alekseeva, M. Tomczak and K. Svedhage. 2006. “Why they came: The colonization of the coast of western Sweden and its environmental context at the end of the last glaciation.” *Oxford Journal of Archaeology* 25(1): 1–28.

Schulting, R. J. 2015. “Mesolithic skull cults?” In *Ancient Death Ways Proceedings of the Workshop on Archaeology and Mortuary Practices*, edited by K. V. Hackwitz and R. Peyroteo-Stjerna, 19–46. Occasional Papers in Archaeology 59. Uppsala: Uppsala University.

Sjögren, K.-G. and T. Ahlström. 2016. “Early Mesolithic burials from Bohuslän, western Sweden.” In *Mesolithic burials—Rites, Symbols and Social Organisation of Early Postglacial Communities*, edited by J. M. Grünberg, B. Gramsch, L. Larsson, J. Orschiedt and H. Meller, 125–143. International Conference Halle (Saale), Germany, 18th–21st September 2013. Halle: Tagungen des Landesmuseums für Vorgeschichte Halle 13.

Smith Jr., W. and D. Nelson. 1985. “Phytoplankton biomass near a receding ice-edge in the Ross Sea.” In W. Siegfried., P. Condy and R. Laws, 70–77. *Antarctic nutrient cycles and food webs.* Berlin: Springer.

Smith, W. O., and D. M. Nelson. 1986. “Importance of ice edge phytoplankton production in the Southern Ocean.” *BioScience* 36(4): 251–257.

Stiner, M. C. 2001. “Thirty years on the ‘Broad Spectrum Revolution’ and paleolithic demography.” *Proceedings of the National Academy of Sciences* 98: 6993–6996.

Stiner, M. C. and N. D. Munro. 2011. “On the evolution of diet and landscape during the Upper Paleolithic through Mesolithic at Franchthi Cave (Peloponnese, Greece).” *Journal of Human Evolution* 60: 618–636.

Storå, J. 2001. *Reading Bones: Stone Age Hunters and Seals in the Baltic.* Stockholm: Jannes Snabbtryck Kuvertproffset.

Svedhage, K. 2005. “Analysrapport avseende biostratigrafiska/geologiska undersökningar på Morlanda 89 och Morlanda 491.” In *Huseby Klev, en kustboplats med bevarat organiskt material från äldsta mesolitikum till järnålder, Bohuslän, Morlanda socken, Huseby 2:4 och 3:13. RAÄ 89, 485*, edited by B. Nordqvist, 109–112. Mölndal: Riksantikvarieämbetet, UV Väst.

Svendsen, F. 2018. “Seal and Reindeer: Immediate and continuous utilization of coast and mountain in the early Mesolithic of Northwestern Norway.” In *The Early Settlement of Northern Europe: Conditions for Subsistence and Survival,* edited by P. Persson, B. Skar, H. M. Breivik, F. Riede and L. Jonsson, 355–379. The Early Settlement of Northern Europe, volume 1. Sheffield: Equinox Publishing.

Tuck, J. A. 1976. *Ancient people of Port au Choix: The Excavation of an Archaic Indian Cemetery in Newfoundland.* St. John’s: Institute of Social and Economic Research Memorial University of Newfoundland.

Turnbull, P. F. and C. A. Reed. 1974. “The Fauna from the Terminal Pleistocene of Palegawra Cave, A Zarzian occupation site in Northeastern Iraq.” *Fieldiana Anthropology* 63(3): 81–146

White, T. E., 1952. “Observations on the butchering technique of some aboriginal peoples.” *American Antiquity* 17(4): 337–338.

Widmark, G. 2015. “Huseby Klev en jämförelse mellan kust och inland, en studie om jaktstrategier och resursutnyttjande under mesolitikum.” *Seminar paper in Historical Osteology.* Lund: Department of Archaeology and Ancient History, Lund University.

Paper V

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The importance of freshwater fish in Early Holocene subsistence: Exemplified with the human colonization of the island of Gotland in the Baltic basin

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ABSTRACT

In this paper we explore the subsistence economy of the Mesolithic pioneers on the island of Gotland in the Baltic basin, in order to evaluate the importance of freshwater fish to the Early Holocene human population. By analysing faunal remains, the distribution of ^{14}C dates and the location of the settlement sites, we argue that earlier assumptions concerning the importance of marine mammals to the early human populations should be reconsidered. We suggest that the pioneering settlers of Gotland relied on fish to a significant extent. Radiocarbon dates taken from human bones are skewed by a freshwater reservoir effect, which can be used as an indirect indication of the significance of freshwater fish. The numerous, overgrowing lakes on the island, with their extensive biomass production and large amounts of freshwater fish, provided an important subsistence base. Even if the faunal assemblages that have survived are dominated by seal bones, the hunting season for seals was limited and the hunters mostly targeted young seals. Thus, the importance of seal have previously been overestimated and it appears that the human use of marine resources on Gotland was more limited and related to raw material needs rather than dietary necessity or specialization. Although presented as a case study; the results highlight the need to identify a freshwater fish diet among ancient foragers on a larger scale, as implications thereof can fundamentally change how foraging societies are perceived.

1. Introduction

It is notoriously difficult to investigate (freshwater) fish dependency among ancient human populations. Site refuse faunal remains are affected by preservation bias as the fragile fish bones may not be preserved and, furthermore, special field recovery techniques are required in order to secure sufficient retrieval efficiency (see e.g. Segerberg, 1999; Enghoff, 2007; Payne, 1972). However, as an understanding of the subsistence patterns profoundly affects our understanding of past societies, it is important that new venues constantly are being investigated and evaluated. A dependency on fish may be very important among foragers and, thus, the possibility to prove a (freshwater) fish dependency would significantly affect how to interpret the subsistence of such social groups or societies and also change our view on mobility, demography, complexity and territoriality, etc. These parameters may change in relation to the utilization of aquatic resources and are often connected to sedentism and growing social complexity (Ames, 1994; Binford, 2001; Kelly, 2013). We here present an attempt to investigate the importance of freshwater fish in an Island context, namely the pioneer Mesolithic population on the Island of Gotland in the Baltic Sea. The methodology presented can be applied elsewhere and is, in general, also applicable in other contexts.

The earliest colonization of the island of Gotland in the Baltic basin (Fig. 1) began c. 9200 cal. BP (Lindqvist and Possnert, 1999), i.e. in the late Early Mesolithic period in Scandinavia and during the initial phase of the Littorina Sea when small amounts of saline water entered the Baltic basin through the Dana river (Andrén et al., 2011). In earlier research of the refuse fauna from the pioneer settlements, evidence of rich marine resources, including grey and ringed seal colonies, has been interpreted as the major pull factor for attracting people to the island (Pira, 1926; Schnittger and Rydh, 1940; Clark, 1976; Österholm, 1989; Lindqvist and Possnert, 1999; Wallin and Sten, 2007; Andersson, 2016). In contemporaneous inland environments of mainland Scandinavia, terrestrial mammals have been seen as the most important subsistence source (Jochim, 2011; Schmitt et al., 2009; Blankholm, 1996), but as these animals were absent of the Island of Gotland seals were

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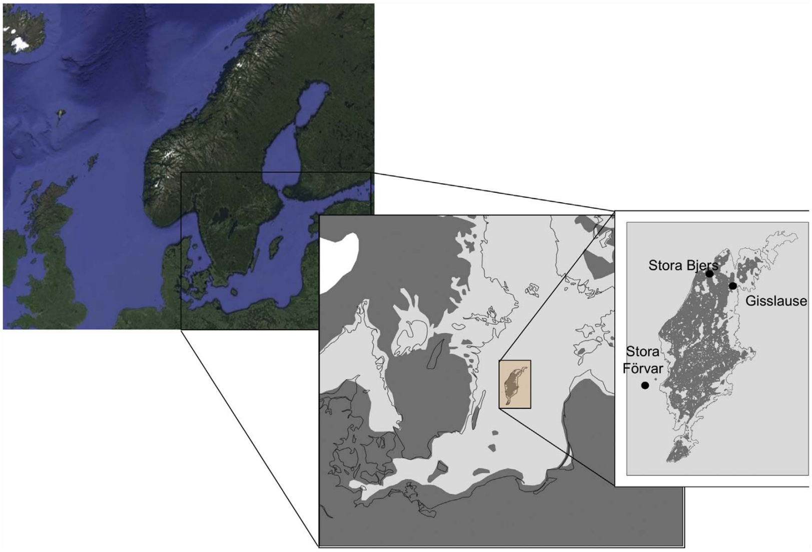

Fig. 1. A map of Gotland indicating the Mesolithic shorelines and sites discussed in the text.

considered the most important prey. The tendency to view terrestrial mammals on Scandinavian mainland and seals on Gotland as the primary food sources is probably related to the limited amount of fish bones found in Scandinavian Early Mesolithic contexts. As a result, the idea of a freshwater fish-dependent Mesolithic economy has not been considered, or been marginalized, even though numerous finds of bone leisters—finely toothed bone point used for spearfishing—in south Scandinavian bogs and submerged fish traps from Haväng in south-east Scandinavia, suggests otherwise (Andersen, 1978; Johansson, 2006; Hammarstrand Dehman and Sjöström, 2008; Hansson et al., 2016).

However; more than 30 years ago, and based on investigations of sediments including fish bones in the Spjälkö lagoon in south-east Sweden, Welinder (1978) stressed the possible importance of freshwater fish for Mesolithic demographics. He based his arguments on estimations of the biomass productivity of lakes that were becoming overgrown/silted up by excessive plant biomass production because of eutrophication, during the early post-glacial period (Welinder, 1978). Welinder suggested that the Maglemose culture in southern Scandinavia was an adaption to boreal environments, where overgrowing lakes, rich in biomass and freshwater fish, played a crucial role for human subsistence. This novel economic niche was utilized by hunter-gatherer groups that based their subsistence on freshwater fish complemented by large terrestrial game and hazelnuts, which were an abundant resource in the light birch-pine-hazel forests. A decade after Welinder made his initial suggestions, Ericson (1989) raised a general concern about underestimating the importance of fish (in comparison with seals) from a taphonomic viewpoint, i.e. an identification and preservation bias against fish, and he also highlighted the predictability of capture, regarding fish as a more stable and reliable resource than seal.

In southern Scandinavia, the interpretation of a subsistence based on hunting of terrestrial game has been enhanced by the general absence of evidence of settlements close to large water bodies during the Early Mesolithic period. This absence is largely the result of sea level transgressions following the last ice age, which left coastal areas submerged and in many areas inaccessible to ‘standard’ archaeological excavation. However, marine archaeological excavations have been an option for submerged sites (Fischer, 1995; Hansson et al., 2016). Furthermore, recent evidence also suggest that the primary reason for hunting terrestrial mammals may not have been meat (even though that was an important resource) but raw materials such as tendons, skins, bones and antlers (Boethius, 2017b).

The absence of fish bones in many archaeological faunal assemblages arises from poor preservation and inappropriate recovery techniques during excavation, but even when fish bones do occur at archaeological sites it is often difficult to evaluate their representation. Fish bones are more susceptible to diagenetic forces compared with mammal bones, because of their small size and fragility, and they are difficult to retrieve if smaller mesh sieves are not used (Segerberg, 1999; Olson and Walther, 2007; Enghoff, 2007; Boethius, 2016). However, despite the bias of both preservation and recovery methods, the importance of freshwater fish during the Early Mesolithic on mainland southern Scandinavia has recently been strengthened by the detailed recovery methods applied at the site of Norje Sunnansund in Blekinge on the south-east coast of Sweden. Extensive quantities of freshwater fish bones have been recovered (Boethius, 2016, 2017a) and the subsistence base is considered to have been fish, which could provide both a constant supply of fresh food and a surplus that could be processed for storage (Boethius, 2016). The calculated volume of fish consumed at Norje Sunnansund suggests that this resource could have supported a large sedentary population (Boethius, 2017a).

Human stable isotopes (δ^{13}C and δ^{15}N) have also been used to study diet, and a freshwater fish presence has been suggested at the Kams burial on Gotland (Lidén, 1996), in Middle Mesolithic eastern Sweden (Eriksson et al., 2016) but also on the Early Preboreal site Friesack 4 in northern Germany (Terberger et al., 2012). However, while elevated levels of δN^{15} with corresponding low δC^{13} values in human bones rather reliably indicate large amounts of freshwater fish in the consumed diet, individuals who do not display an equally high elevation in δN^{15} values may still have consumed large amounts of freshwater fish. This is due to the overlapping baselines between low trophic level freshwater fish (cyprinids) and terrestrial mammals (compare cyprinid δN^{15} values with δN^{15} values from terrestrial herbivores in Schmölcke et al., 2015 and Fischer et al., 2007). Furthermore, large variations in δC^{13} values in freshwater fish have been noted between different freshwater systems (Milner et al., 2004) and even between freshwater fish within the same lake (Hecky and Hesslein, 1995), depending on where and at what depth of the lake each fish species lives (Katzenberg and Weber, 1999; Katzenberg et al., 2009). This makes δC^{13} values in human collagen difficult to interpret when a large input from freshwater fish is suspected in the diet. In addition, recently some issues have been reported relating to the determination of the fractionation factor (δN^{15} and δC^{13}) between consumer and prey, which have been shown to vary according to different environmental and biological factors (Dalerum and Angerbjörn, 2005; Florin et al., 2011; McCutchan et al., 2003; Vanderklift and Ponsard, 2003). Especially δN^{15} have been observed to vary greatly and in general show higher fractionation rates than have previously been considered (Ambrose, 2000; Bocherens and Drucker, 2003; Caut et al., 2008, 2009; Hussey et al., 2014; Jenkins et al., 2001; O'Connell et al., 2012; Sponheimer et al., 2003). Thus, even though analysis of stable isotopes can be rather confidently used if overlapping baselines and varying fractionation factors are appropriately accounted for (Boethius & Ahlström, forthcoming), it is important that freshwater fish consumption can be identified using other kinds of data.

The osteoarchaeological results from Norje Sunnansund, and the arising insights concerning the Early Mesolithic economy of southern Scandinavia, call for a reconsideration of the importance of fish also on the island of Gotland. Thereby, a re-examination of the subsistence strategies used by the pioneering settlers is warranted. We have addressed this by analysing the freshwater fish bones and seal bones recovered from a recently excavated site at Gisslause. We have also examined a large series of radiocarbon dates from Early and Middle Mesolithic Gotland and highlight issues concerning the dating of human bones.

2. The Gotland sites

2.1. Gisslause, Lärbro Parish

The Mesolithic site at Gisslause was discovered 1928. A cultural layer containing charcoal, stone, flint and bone artefacts, faunal and other organic remains was revealed underneath a c. 1-m thick sterile layer of sand, gravel and chalk stones deposited by the Littorina I transgression, which reached its maximum at c. 7600 cal. BP (Risberg et al., 2007) (Fig. 2). The cultural layers can therefore be considered to be closed contexts (Munthe and Hansson, 1930; Seving, 1986; Apel and Vala, 2013), and the site was undoubtedly abandoned before the Littorina maximum, probably before 8000 cal. BP, perhaps as a result of the 8200 cal. BP cold event (Alley and Ágústsdóttir, 2005).

The site was originally excavated in the summer of 1929 and was revisited 1982. The finds from the early excavations included worked Ordovician flint, bone tools, bones from seal, mountain hare and birds, as well as carbonized hazelnut shells, shells of white-lipped and bush snails and pine wood fragments, a hearth and a ground stone axe of the Scandinavian Limhamn type (Munthe and Hansson, 1930; Seving, 1986; Burenhult, 1999:49). Small soil samples from the cultural layer were analysed under laboratory conditions and bones from fish species such as pike, roach and rudd were recovered (Munthe and Hansson, 1930).

In 2010, Gotland University conducted a new excavation of the site (Apel and Vala, 2013). The primary aim of this excavation was to see whether there were any fish bones in the cultural layer. Consequently, samples from the cultural layer were systematically water sieved through 4-mm and 2-mm meshes. Three small trenches were excavated south of the two previous excavation areas, and a feature interpreted as a hearth was recovered (Fig. 3). The resulting faunal assemblage from Gisslause comprised 3271 specimens: 788 seal (85 ringed seal and 64 grey seal) fragments, 33 hare, 594 fish, 47 bird and 1809 indeterminate fragments. The bone material from Gisslause is one of only a few faunal assemblages from Early Mesolithic settlements on Gotland. Furthermore, it is the only Early Mesolithic site with preserved fish bones except for Stora Förvar, which is a specialized seal hunting site rather than a settlement (Apel and Storå, 2017) and the fish bones from there were not recovered systematically.

2.2. Stora Förvar, the island of Stora Karlsö

The cave sequence at Stora Förvar on the small island of Stora Karlsö, c. 5 km west of Gotland, was excavated during 1888–1893 (Pira, 1926; Schnittger and Rydh, 1940; Lindqvist and Possnert, 1999; Apel et al., 2015; Apel and Storå, 2017). The cave is c. 25 m deep and the original cultural layers, which were over 4 m thick, were excavated in sections (A–I) and mechanical 0.3-m thick spits. The cave contained finds from the Early Mesolithic to historical periods. Large amounts of faunal remains, mainly of seal bones, were recovered from the site, and the excellent preservation of the bones allowed osteometric data to be compiled that indicated the seasonality of the seal hunt but also the prey choices of the hunters (Apel and Storå, 2017). The faunal assemblage in the Mesolithic layers of section F (layers 13–10 from the 1891–92 excavations) was dominated by seal bones, 10,242 of a total of 10,358 fragments. Only 41 fragments were identified as fish, 39 as bird, 2 as hare and 16 as other terrestrial mammals, of which at least 8 were later intrusions (e.g. domestic pig) (see also Apel and Storå, 2017). The finds also included 18 human bones. The small number of fish bones was biased by the recovery technique used.

2.3. Stora Bjärs, Stenkyrka Parish

The Stora Bjärs burial (Arwidsson, 1979) is the only known closed find context from the Early and Middle Mesolithic periods of Gotland where terrestrial fauna and human remains can be accelerator mass spectrometry (AMS) dated and compared. It was revealed in 1954 during an excavation of a Bronze Age site, and was lifted and taken in one piece to the Museum of Gotland to be excavated further. Along with the skeleton of an adult male in a hocker position, the grave contained two red deer antler tines, probably used as flint-knapping tools, the tip of a slotted bone point, and six pieces of flint, including a couple of blades/microblades (Arwidsson, 1979).

3. Methods

3.1. Radiocarbon dates

We compiled a total of 63 AMS dates from the Mesolithic layers at Stora Förvar and Gisslause. The radiocarbon dates from the oldest layers at Stora Förvar came from 20 human samples, 8 seal samples, 10 terrestrial or nutshell samples, 4 pike samples and 4 salmon samples. From Gisslause the dates came from a series of 15 samples, from 2 carbonized hazelnut shells, 9 fish, 2 hare and 1 seal from the 2010 excavation, and an unsourced charcoal sample from the hearth that was recovered in 1982 (Seving, 1986). Two dates were included from the Stora Bjärs inhumation burial; 1 from human and 1 from red deer (Arwidsson, 1979).

3.2. Faunal analysis

The seal bones were analysed using the comparative collection at the Osteoarchaeological Research Laboratory, Stockholm University, Sweden (by CHV, JS). The fish bones were analysed using the comparative collection at National Historical Museums, Lund, Sweden, and the collection at the Department of Archaeology and

Fig. 2. Left: profile photo of the site at Gisslause from 1929. a = c. 1-m thick transgression layer; b = cultural layer, c = the top of the late glacial esker (Munthe and Hansson, 1930:267). Right: the cultural layer in a section from the 2010 excavation, seen as the dark layer in the trench floor.
(Photo: Jan Apel).

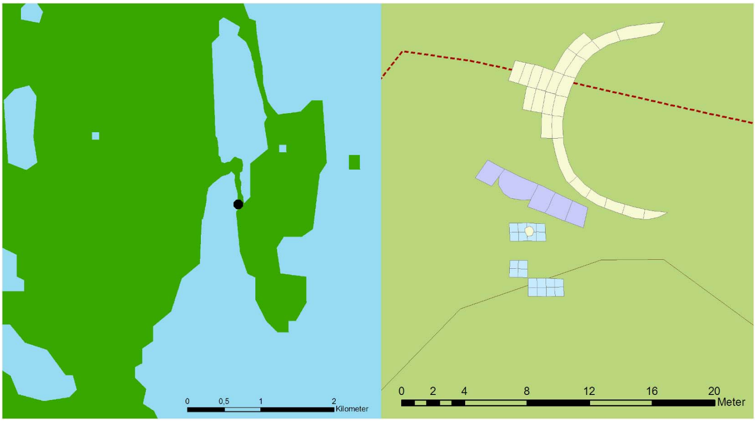

Fig. 3. The site at Gisslause was positioned strategically on a small esker between a shallow lake and a bay of the Baltic, shown in the geographical information system (GIS) reconstruction on the left. The excavation plan (right) shows the location of the trenches from the 1928 excavation (in yellow), 1982 (purple) and 2010 (light blue). The red dotted line represents the middle of a road. (GIS: Amanda Karn). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Ancient History, Lund University, Sweden (by AB). The ageing of seal bones based on epiphyses followed the criteria presented in Storå (2001, 2002), while osteometric analyses of seal bones followed the definitions in Ericson and Storå (1999). Comparative metric data from extant seals were collected at the Swedish Natural History Museum, Stockholm, Sweden.

4. Results

4.1. The fish bone assemblage from Gisslause

The fish bone assemblage from Gisslause comprised 594 specimens, of which 423 were identified to species (Fig. 4). Bones of cyprinids and burbot were the most common, followed by pike, perch and whitefish. The species distribution was interesting because only freshwater species were present, indicating an intensified fishing of both cyprinids and burbot. The relatively large amount of burbot was intriguing, as burbot is most often caught during the winter, when it is active during the day and gathers in shallow waters to spawn, as opposed to the summer, when it is active during the night and resides in deep waters (Kullander et al., 2012), and thus more difficult to catch. Because burbot is most commonly caught during the winter, by clubbing through the ice, the abundance of burbot bone implied that the site was used during the winter and that the people used land-based (walking from the shore) methods to catch the fish. It was also of interest that cyprinids were the most commonly represented fish and that salmon and trout species

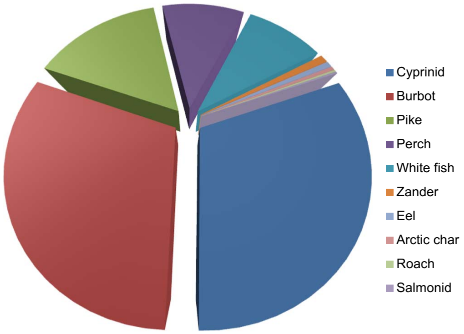

Fig. 4. The fish bones from the 2010 Gisslause excavation. Number of identified specimens (NISP) = 423: cyprinid (*Cyprinidae* sp.) = 131, burbot (*Lota lota*) = 128, pike (*Esox lucius*) = 67, perch (*Perca fluviatilis*) = 45, whitefish (*Coregonus* sp.) = 41, zander (*Sander lucioperca*) = 4, eel (*Anguilla anguilla*) = 3, Arctic char (*Salvelinus alpinus*) = 2, roach (*Rutilus rutilus*) = 1, salmonid (*Salmonidae*) = 1.

were rare. The same pattern was observed at Norje Sunnansund, where cyprinids made up almost 75% of the identified fish bones and salmons were only represented by a handful of fragments corresponding to less than 1‰ of the identified specimens. The species distribution therefore indicated that Gisslause and Norje Sunnansund had two things in common: (i) they were not located near areas of anadromous fish runs and (ii) fishing did not appear to be carried out on open water, but rather in small shallow lakes and/or the streams leading up to them.

The element distribution suggested that the assemblage had been subjected to a large taphonomic loss (Fig. 5). This was indicated by low frequencies or a complete absence of head and shoulder fragments from all species except pike and cyprinids. This is a common pattern when preservation is less than perfect. A high representation of cranial fragments from pike is often seen as these elements are more robust in pike than in other species. In light of this, it might seem significant that the small cyprinids were also represented by a relatively large amount of cranial fragments, however 89% of these were of pharyngeal elements, which are the hardest and most dense cyprinid bones. Pharyngeal elements are also the most commonly encountered cyprinid cranial fragments at archaeological sites.

When comparing the fish bone material from Gisslause with other Early Mesolithic sites, it is important to consider that only 5 m^2 have been excavated and water sieved so far, which has generated 423 identifiable fish bones. In comparison, at the preliminary investigation at Norje Sunnansund 3 m^2 of the Early Mesolithic cultural layer were excavated, from which 6 L of soil were water sieved. This generated 160 identifiable fish bones (Boethius and Magnell, 2010). The final excavation, of 842 m^2, at Norje Sunnansund generated around 200,000 fish bones (Kjällquist et al., 2016). Thus, the density of fish bones at Gisslause was noteworthy and highlighted the importance of freshwater fish on Gotland.

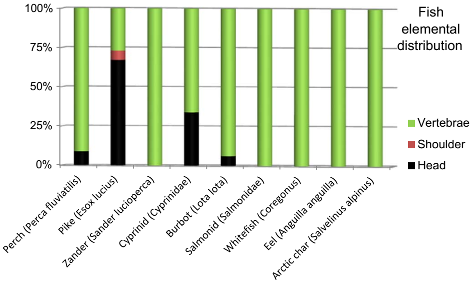

Fig. 5. Gisslause fish bone element frequency.

4.2. Seal exploitation

An examination of the seal bone assemblage from Gisslause and Stora Karlsö, in particular the seasonality of the seal hunting and prey choice, revealed some notable patterns regarding the hunting practices of Mesolithic settlements on Gotland. At Stora Karlsö, hunting appeared to be heavily biased towards young grey seal (Apel and Storå, 2017). Ringed seal became more common in the younger Mesolithic layers in the cave (Fig. 6), an increase that was characterized also by an increase in the presence of older, adult, ringed seals (Fig. 7, see also Apel and Storå, 2017). The assemblage from Gisslause was similarly dominated by bones of younger seals, but with the frequency of species corresponding to that of layer F8 in the Stora Förvar cave, i.e. a comparatively higher frequency of ringed seal. The Mesolithic layers lacked bones of the harp seal, which entered the Baltic basin during the Atlantic period and in the Littorina Sea phase. Thus layer F8 probably contained finds from the last phase of the pioneer settlement but also some intrusions of Late Mesolithic finds. There was a 2000-year hiatus in the dates between the two phases (Lindqvist and Possnert, 1999; Apel et al., 2017). Layer F6 contained Middle Neolithic, Pitted Ware Culture, finds, when the cave site was used during the hunting of ringed seal.

Osteometric comparisons of unfused femora from subadult seals highlighted the seasonality of the hunting (e.g. Storå, 2001, 2002). There was a difference at Stora Karlsö in hunting pattern between the oldest layers of the cave (F13–12) and the youngest layers (F8–9). The oldest layers contained more ‘larger’ subadult grey seals than the younger layers. This was evident, for example, by the fact that 60% of the femora were larger than c.45 mm in layers F13–12, while the corresponding frequency was c. 20% only in the youngest layers (F8–9) (Fig. 7). Thus, over time at Stora Karlsö, the focus shifted away from the hunting of older subadult grey seals and older yearling grey seals, i.e. the hunting season was shortened. The hunting season for ringed seal remained largely unchanged (see Apel and Storå, 2017). Because of poor preservation it was difficult to obtain metric data from the bones at Gisslause. Four radii and three femora of ringed seal exhibited a size variation that corresponded to seals less than c. 2–3 months of age, while no postcranial bones of grey seal could be documented. Two temporal bones exhibited sizes characteristic of yearlings but using this element for ageing is difficult.

The age structure of the hunted seals was also investigated using epiphyseal fusion data. The division of age groups follows Storå (2001) where AG1 comprise of elements that fuse during the first year of life, i.e. in yearling; AG2 elements that fuse as subadults; AG3 elements that fuse as young adults; and AG4 elements that fuse as old adults. These categories may be related to life history and behavioural patterns Storå (2001). The epiphyseal data from Gisslause and Stora Förvar showed that bones from adult seals were uncommon (Fig. 8). This was evident, for example, in the low level of fusion of vertebral discs to the vertebral corpus. Interestingly, there was a slight difference in the age structure for the flipper bones compared with the long bones and vertebrae (Fig. 8). The level of fusion of the flipper bones was higher than the elements from other regions. The difference was more marked for Gisslause than Stora Förvar, possibly indicative of selective transport of carcass parts, i.e. older adult seals were represented mainly by flipper bones and not the body, and the flippers may have been attached to skins. In contrast, complete carcasses of younger seals appeared to have been transported to the site more often. This pattern was not as evident at Stora Förvar (Fig. 8), but here the assemblage contained very few bones from adult seals.

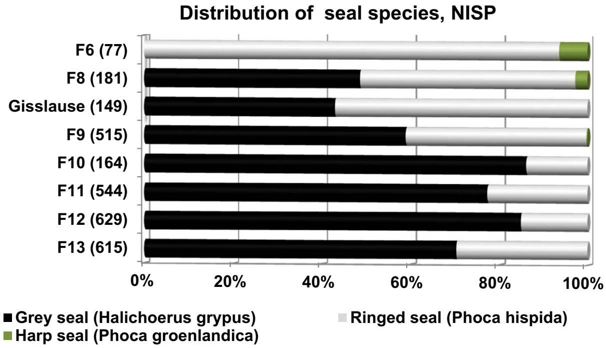

Fig. 6. The distribution of seal species (NISP) in different layers from Stora Förvar and Gisslause.

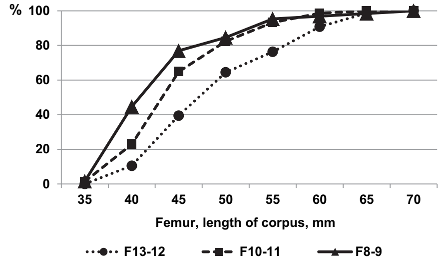

Fig. 7. Size distribution (cumulative frequency of size classes) of grey seal femora from different layers at Stora Förvar.

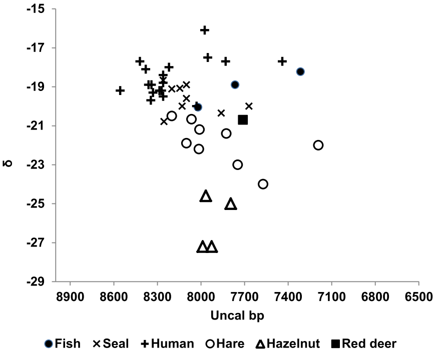

Fig. 9. The distribution of radiocarbon dates and $\delta^{13}C$ values from Stora Förvar, Gotland. Full data are provided in the Supplementary material.

4.3. Radiocarbon dates and freshwater reservoir effect

The 12 oldest dates from Stora Karlsö were from human samples (Fig. 9 and Supplementary material). Even if the find circumstances of the sample were not optimal, it was noteworthy that there was a difference between the human dates and dates from other animal and material samples. There appeared to be approximately 100 years between the dates of the human bones and those of seals (and pike), but there was an approximately 300-year offset between the oldest and the youngest dates from the human bones and terrestrial mammals as well as between the average age of human bones compared with terrestrial mammals (Table 1).

There was a similar difference between the Stora Bjärs male human and red deer tine from the same burial: the red deer tine was dated to 7711 ± 51 uncalibrated bp (Ua-46146) while a tooth from the male human was dated to 7974 ± 49 (Ua-46147). Bearing in mind these samples originated from a closed context, while initially it appeared that the human was several hundred years older than the red deer tine,

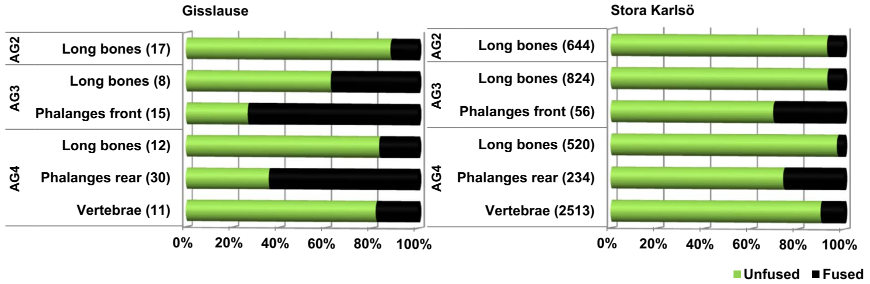

Fig. 8. Epiphyseal fusion data for seals (*Phocidae*) from Gisslause (left) and Stora Förvar (right) (F13–10). Age group division according to Storå (2001). The frequencies present the ratio between fused and unfused diaphyseal elements (loose, unfused epiphyses were excluded).

Table 1
Number and source of the AMS dates from Stora Förvar (uncalibrated bp).

Source	Oldest	Youngest	Average
Human (n = 20)	8555	7440	8195
Pike (n = 4)	8160	8020	8103
Seal (n = 8)	8260	7670	8108
Salmon (n = 4)	8075	7315	7783
Terrestrial herbivore and hazelnuts (n = 10)	8200	7192	7865

if a 300-year offset is subtracted from the uncalibrated bp value of the human date, the red deer tine and the human dates align, implying a reservoir effect. More accurate age estimations for human remains from Mesolithic Gotland could probably be reached by subtracting c. 300 years from the bp values (Figs. 10–11, green tinted). Therefore, in order to evaluate more precisely the reservoir effect, an attempt was made to date fish bones from Gisslause. Unfortunately, this proved to be impossible because of diagenetic alteration of the collagen in the fish bones (see the Supplementary material).

5. Discussion

The AMS dates from human bones were systematically older than the dates from all other sources, which suggests that a reservoir effect had affected the human samples. We can confidently rule out a strong marine reservoir effect because the Baltic basin was isolated from the Atlantic Ocean via a land bridge, where modern-day Öresund now connects the two water bodies (Fig. 1). In the Baltic the marine effect has been estimated to be no more than 100 years during the Mesolithic period, i.e. during the initial Littorina phase (Lindqvist and Possnert, 1999:79). Even in the Neolithic period, during the main Littorina phase, when the Baltic was more saline than during the Mesolithic, the pioneer settlement phase has been estimated as lasting around 70 years (Eriksson, 2004). If affected by a marine reservoir effect, the dates of seal (cubs), lacustrine pike and salmon from Stora Karlsö, all presumably living in the Baltic basin, should correspond to or in fact be somewhat older than the human dates. However, the observed radiocarbon offset is around 300 years in the opposite direction. Therefore, it appears that the dates from human bones are affected by a freshwater reservoir effect, known to affect organisms living in freshwater or feeding on a freshwater diet (Philippsen, 2012). The freshwater reservoir effect is the difference between the age of freshwater carbon reservoirs and the age of atmospheric or terrestrial carbon reservoirs (Ascough et al., 2010; Philippsen, 2013; Coularis et al., 2016). Humans that consume large amounts freshwater fish from hard-water reservoirs rich in dissolved ancient calcium carbonates (in lakes or streams) have raised levels of old and ^{14}C-depleted carbon in their systems (Philippsen, 2013). As the bedrock of Gotland consists of limestone sediments, the hard-water effect is likely to have had a major impact in the lakes and possibly to some degree in the lacustrine zones around the island (as a result of water from the river outlets being mixed with the water from the Baltic basin). In fact, a recent study based on radiocarbon dating of the bivalve mollusc genus Macoma, from pre-nuclear museum specimens of known calendar age, clearly show that the coastal area around Gotland is subjected to the most significant hard-water reservoir effect detected in the entire Baltic basin, due to the freshwater runoff from Gotlandic streams adding C^{14} depleted carbon into the surrounding ocean (Lougheed et al., 2013). A detailed evaluation of the reservoir effect needs further consideration, but we emphasize the fact that the human remains appear to exhibit a freshwater reservoir effect that is most probably associated with the human consumption of freshwater fish.

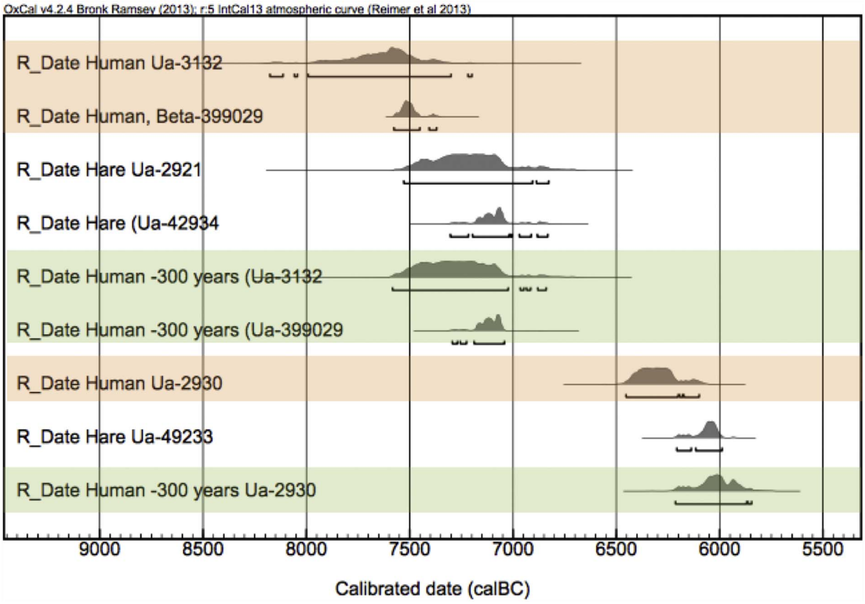

Fig. 10. Calibration of the AMS dates from the two oldest human samples and the two oldest hare samples, and the youngest human sample and the youngest hare sample, from the Early and Middle Mesolithic layers of the Stora Förvar cave sequence. Red tint, calibration interval of human bp dates; green tint, calibration interval of human bp dates − 300 years. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

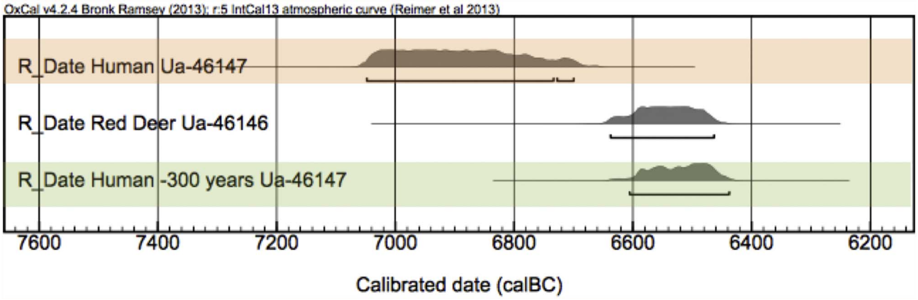

Fig. 11. Calibration of AMS dates from a human tooth and red deer tine from the Stora Bjers burial. Red tint, calibration interval of human bp dates; green tint, calibration interval of human bp dates − 300 years. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

The magnitude of a freshwater reservoir effect affecting the radiocarbon dates should be different for different animals and materials. Freshwater fish from lakes on main Gotland should be affected the most and humans living on freshwater fish the second most. Littoral fish and seal cubs should be affected less than humans, and anadromous fish (e.g. salmon, who spend most of their lives offshore) and fully grown seals even less. Finally, terrestrial mammals and hazelnuts should not be affected at all. This fits with what can be observed in the ^{14}C dates (Table 1, Fig. 9) from Stora Karlsö, where the average age of these groups aligns with the effect described above, except for the salmon bones, which are somewhat younger than the average terrestrial materials, but this could be the result of sample issues.

If a freshwater reservoir effect is at play, we would expect the oldest uncalibrated radiocarbon dates in this study to come from bones of freshwater fish living in lakes on Gotland. It was therefore considered important to investigate dates from main Gotland freshwater fish, because these bones should display older uncalibrated bp values than human bones. However, we were not able to investigate this because our fish sample from Gisslause was affected by diagenesis, rendering interpretations impossible (see Supplementary material). In the absence of fish radiocarbon dates, the finds from the sealed Early Mesolithic contexts are very important as an indicator of freshwater fish consumption. Thus, the dating sequence from Stora Karlsö and the dates from the Stora Bjärs inhumation provide the best evidence so far of a freshwater reservoir effect within Early Mesolithic humans. This, in turn, provides a strong indication of the importance of freshwater fish to the subsistence of Mesolithic pioneers on Gotland, and freshwater fish can therefore be considered more important than previously suspected.

Humans living on mainland Sweden had the opportunity to venture inland to hunt terrestrial mammals, but on Gotland no larger terrestrial mammals were available. Seal hunting would therefore have been important on the island, but possibly not primarily as an invaluable food source. Seals may have been hunted for their skins, tendons and blubber, for example, as well as contributing to the human diet. The amount of seal caught, as indicated by the thousands of kilos of seal bones found in the Stora Förvar cave, indicates an extensive need for these products. However, more detailed examination of the seasonality of the hunting patterns reveals that the seal hunting was directed towards younger seals. The focus on young, and small, seals may have necessitated many seals being killed, but during a short period of the year. The hunting season for seals is not year-round; in the lowest layers at Stora Karlsö the season may have been as long as 6 months but it was shorter in the youngest phase. We do not have detailed data from Gisslause but the few complete bones at the site came from young seals. Many appeared to have been killed in their first months of life, i.e. late winter and/or early spring, which corresponds well with the seasonal hunting of seals indicated at Norje Sunnansund (Boethius, 2017b). Thus, for at least half of the year, and in the youngest layers of Stora Förvar, and probably also Gisslause, for most of the year, seal hunting seems to have been limited. This is another indirect indication of the probable importance of fish to the Mesolithic settlements.

The Stora Karlsö island and cave apparently became a specialized site for raw material extraction. The settlement at Gisslause may have had a slightly different focus, being located on main Gotland and close to freshwater resources. If considered in the context of complex societies, special extraction points or sites suggest control of the environment (Kelly, 2013) and so provide a possible indication of a non-egalitarian society in the making. On mainland Scandinavia, hunters left the sedentary settlements to hunt larger mammals inland during the summer, as demonstrated by only summer seasonal indicators on all inland settlements in southern Scandinavia (Rowley-Conwy, 1993; Carter, 2001; Price, 2015:115). There is also a decline of summer seasonality indicators on the only known Early Mesolithic east coast site with preserved organic remains, Norje Sunnansund (Boethius, 2017b). However, the seal hunts on Gotland seem to have occurred mainly during late winter and early spring.

The interpretations of the present study are in contrast to earlier views on the economy of the pioneers of Gotland (Pira, 1926; Schnittger and Rydh, 1940; Clark, 1976; Österholm, 1989; Lindqvist and Possnert, 1999; Wallin and Sten, 2007; Andersson, 2016), where maritime and marine resources were seen as the main pull factor. Thus, the pioneer settlements on Gotland may be viewed in a broader context. Returning to Welinder (1978); he highlighted the possible importance of freshwater resources, but also anticipated a chronological-geographical gradient for this type of adaptation. The earliest sites characterized by this lifestyle are found on the British Isles (e.g. Starr Carr) and in northern Germany (e.g. Duvensee), and the adaptation reached southern Scandinavia later (Welinder, 1978; e.g. the bog sites at Ageröd and Bare Mosse). It is likely that competition for decreasing resources forced groups to move into new areas. As most of the shallow lakes were eventually overgrown, human groups needed to move north, reaching the lakes of inner Småland (Persson, 2012) and possibly Gotland c. 9000 years ago. Thereby, our results indicate that the first pioneers may have been pushed rather than pulled to Gotland. It is interesting to note that the Boreal habitation sites of Gotland, with the obvious exception of Stora Förvar, are located on the northern part of the island. Here the numerous lakes, in contrast to the deep, headwater lakes of southern Gotland, were shallow, overgrowing lakes, suitable for fishing cyprinids, perch, pike and whitefish, etc. This implies that, even though Stora Förvar contains more Mesolithic seal bones and, in fact, more bones in total than all other Swedish sites combined and even though large amounts of seal were caught there, the seals were not the primary source of subsistence for the earliest inhabitants of Gotland. If seals had been a primary component of their diet, human radiocarbon dates would exhibit the same reservoir effect as seals. However, because the human dates were systematically older than the seal dates, we argue that the observed reservoir effect in human bones and the osteoarchaeological record point to the importance of freshwater fish on Gotland. Because of the sensitive biotope connected with this type of environment, it was probably affected markedly by the Littorina transgression. The transgression not only covered earlier habitation sites, but also flooded the land with saline water that affected the productive freshwater environments and in turn affected the pioneer settlements on Gotland.

The results presented here indicate that the pioneer settlers on Gotland may have based their diet on freshwater fish. This has further implications: even though it is notoriously difficult to identify high levels of human freshwater fish consumption in prehistoric societies, the study demonstrates the importance of alternative and complementing methods when investigating subsistence strategies. Furthermore, since a subsistence economy based on aquatic resources is often connected to increasing levels of complexity, sedentism and territoriality it changes our view on Early Holocene foragers in general and stresses the need to investigate the importance of freshwater fish in other geographical areas.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.jasrep.2017.05.014.

References

Alley, R.B., Ágústsdóttir, A.M., 2005. The 8k event: cause and consequences of a major Holocene abrupt climate change. Quat. Sci. Rev. 24, 1123–1149.

Ambrose, S.H., 2000. Controlled diet and climate experiments on nitrogen isotope ratios of rats. In: Ambrose, S.H., Katzenberg, M.A. (Eds.), Biogeochemical Approaches to Paleodietary Analysis. Kluwer Academic Publishers, New York.

Ames, K.M., 1994. The northwest coast: complex hunter-gatherers, ecology, and social evolution. Annu. Rev. Anthropol. 23, 209–229.

Andersen, K., 1978. Smuldpladser i Åmosen. Nationalmuseets Arbejdsmark 1978, 103–110.

Andersson, H., 2016. Gotländska stenåldersstudier. Människor och djur, platser och landskap. Stockholm Studies in Archaeology, Stockholm, pp. 68.

Andrén, T., Björck, S., Andrén, E., Conley, D., Zillén, L., Anjar, J., 2011. The development of the Baltic Sea Basin during the last 130 ka. In: J, H., S, B., P, H. (Eds.), The Baltic Sea Basin. Springer, Berlin.

Apel, J., Storå, J., 2017. The pioneer settlements of Gotland — a behaviour ecology approach. In: Persson, P., Riede, F., Skar, B., Breivik, H.M., Jonsson, L. (Eds.), The Ecology of Early Settlement in Northern Europe: Conditions for Subsistence and Survival. Vol. 1 Equinox Publishing, Sheffield.

Apel, J., Vala, C., 2013. Stenålderslokalen Gisslause I Lärbro sn (raä 413:1). (Unpublished report) Gotland University, Visby.

Apel, J., Storå, J., Landeschi, G., 2015. Ett återbesök i Stora Förvar. Efterundersökning av grottan Stora Förvar, Stora Karlsö, Eksta sn, RAÄ 138:1, Gotland. (Unpublished report) Lund University, Lund.

Apel, J., Wallin, P., Storå, J., Possnert, G., 2017. Early Holocene human population events on the island of Gotland in the Baltic Sea (9200–3800 cal. BP). Quat. Int. 2017. http://dx.doi.org/10.1016/j.quaint.2017.03.044.

Arwidsson, G., 1979. Stenåldersmannen från Stora Bjärs i Stenkyrka. In: Falck, W., Nylén, E., Nylén, K., Schönbäck, B., Svahnström, K. (Eds.), Arkeologi på Gotland. Visby: Gatlandica nr Vol. 14. pp. 17–23.

Ascough, P.L., Cook, G.T., Church, M.J., Dunbar, E., Einarsson, A., McGovern, T.H., Gugmore, A.J., Perdikaris, S., Hastie, H., Fridriksson, A., Gestsdottir, H., 2010. Temporal and spatial variations in freshwater 14C reservoir effects: Lake Mývatn, northern Iceland. Radiocarbon 52 (2–3), 1098–1112.

Binford, L.R., 2001. Constructing Frames of Reference: An Analytical Method for Archaeological Theory Building Using Ethnographic and Environmental Data Sets. University of California Press, Berkeley.

Blankholm, H.P., 1996. On the Track of a Prehistoric Economy: Maglemosian Subsistence in Early Postglacial South Scandinavia. Aarhus Universitetsforlag, Aarhus.

Bocherens, H., Drucker, D., 2003. Trophic level isotopic enrichment of carbon and nitrogen in bone collagen: case studies from recent and ancient terrestrial ecosystems. Int. J. Osteoarchaeol. 13, 46–53.

Boethius, A., 2016. Something rotten in Scandinavia: the world's earliest evidence of fermentation. J. Archaeol. Sci. 66, 169–180.

Boethius, A., 2017a. The use of aquatic resources by Early Mesolithic foragers in southern Scandinavia. In: Persson, P., Skar, B., Breivik, H.M., Riede, F., Jonsson, L. (Eds.), The Early Settlement of Northern Europe – Climate, Human Ecology, and Subsistence. Equinox Publishing, Sheffield In press.

Boethius, A., 2017b. Signals of sedentism: faunal exploitation as evidence of a delayed-return economy at Norje Sunnansund, an early Mesolithic site in south-eastern Sweden. Quat. Sci. Rev. 162, 145–168.

Boethius, A., Ahlström, T., 2017. Fish and Resilience Among Early Holocene Foragers of Southern Scandinavia. (forthcoming).

Boethius, A., Magnell, O., 2010. Osteologisk analys av benmaterialet från område 12 förundersökning inför utbyggnad av E22 sträckan Sölve-Stensnäs. In: Reports in Osteology 2010. 7 Uppdrag Osteologi, Lunds Universitet, Institutionen för Arkeologi och Antikens historia.

Burenhult, G., 1999. Arkeologi i Norden. Natur och Kultur, Stockholm.

Carter, R.J., 2001. Dental indicators of seasonal human presence at the Danish boreal sites of Holmegaard I, IV and V and Mullerup and the Atlantic sites of Tybrind Vig and Ringkloster. The Holocene 11, 359–365.

Caut, S., Angulo, E., Courchamp, F., 2008. Discrimination factors (Δ15N and Δ13C) in an omnivorous consumer: effect of diet isotopic ratio. Funct. Ecol. 22, 255–263.

Caut, S., Angulo, E., Courchamp, F., 2009. Variation in discrimination factors (Δ15N and Δ13C): the effect of diet isotopic values and applications for diet reconstruction. J. Appl. Ecol. 46, 443–453.

Clark G. 1976. A Baltic cave sequence: a further study in bioarchaeology. In Mitcha-Marheim H, Friesinger H, Kerchler H. Editors. Festschrift für Rickard Pittioni zum 70. Geburtstag. Archaeologia Austriaca, 13, 113–123.

Coularis, C., Tisnérat-Laborde, N., Pastor, L., Siclet, F., Fontugne, M., 2016. Temporal and spatial variations of freshwater reservoir ages in the Loire River watershed. Radiocarbon 58 (3), 549–563.

Dalerum, F., Angerbjörn, A., 2005. Resolving temporal variation in vertebrate diets using naturally occurring stable isotopes. Oecologia 144, 647–658.

Enghoff, I.B., 2007. Viking age fishing in Denmark, with particular focus on the freshwater site Viborg, methods of excavation and smelt fishing. In: Plogmann, H.H. (Ed.), International Council for Archaeozoology. Fish Remains Working Group. Meeting (2007). The Role of Fish in Ancient Time: Proceedings of the 13th Meeting of the ICAZ Fish Remains Working Group in October 4th–9th, Basel/August 2005. Verlag Marie Leidorf, Rahden/Westf.

Ericson, P.G.P., 1989. Säl och säljakt i Östersjöområdet under stenåldern. In: Iregren, E., Liljekvist, R. (Eds.), Faunahistoriska studier tillägnade Johannes Lepiksaar. Symposium 26 maj 1988. Report Series No. 3. University of Lund, Institute of Archaeology, Lund.

Ericson, P.G.P., Storå, J., 1999. A Manual for the Skeletal Measurements of the Seal Genera Halichoerus and Phoca (Mammalia: Pinnipedia). Department of Vertebrate Zoology, Swedish Museum of Natural History, Stockholm Available at. http://www.nrm.se.

Eriksson, G., 2004. Part-time farmers or hard-core sealers? Västerbjers studied by means of stable isotope analysis. J. Anthropol. Archaeol. 23, 135–162.

Eriksson, G., Frei, K.M., Howcroft, R., Gummesson, S., Molin, F., Lidén, K., Frei, R., Hallgren, F., 2016. Diet and mobility among Mesolithic hunter-gatherers in Motala (Sweden) — the isotope perspective. J. Archaeol. Sci. Rep.(3 June 2016) Available online. (ISSN 2352-409X).

Fischer, A. (Ed.), 1995. Man and Sea in the Mesolithic: Coastal Settlement above and below Present sea Level: Proceedings of the International Symposium, Kalundborg, Denmark 1993. Oxbow books, Oxford.

Fischer, A., Olsen, J., Richards, M., Heinemeier, J., Sveinbjörnsdóttir, Á.E., Bennike, P., 2007. Coast–inland mobility and diet in the Danish Mesolithic and Neolithic: evidence from stable isotope values of humans and dogs. J. Archaeol. Sci. 34, 2125–2150.

Florin, S.T., Felicetti, L.A., Robbins, C.T., 2011. The biological basis for understanding and predicting dietary-induced variation in nitrogen and sulphur isotope ratio discrimination. Funct. Ecol. 25, 519–526.

Hammarstrand Dehman, K., Sjöström, A., 2008. Mesolitiska lämningar I Rönneholms mosse. Rapporter från Institutionen för arkeologi och antikens historia. Lunds universitet, Nr 2. Lund.

Hansson, A., Nilsson, B., Sjöström, A., Björck, S., Holmgren, S., Linderson, H., Magnell, O., Rundgren, M., Hammarlund, D., 2016. A submerged Mesolithic lagoonal landscape in the Baltic Sea, South-eastern Sweden–Early Holocene environmental reconstruction and shore-level displacement based on a multiproxy approach. Quat. Int. http://dx.doi.org/10.1016/j.quaint.2016.07.059.

Hecky, R., Hesslein, R., 1995. Contributions of benthic algae to lake food webs as revealed by stable isotope analysis. J. N. Am. Benthol. Soc. 14, 631–653.

Hussey, N.E., MacNeil, M.A., McMeans, B.C., Olin, J.A., Dudley, S.F., Cliff, G., Wintner, S.P., Fennessy, S.T., Fisk, A.T., 2014. Rescaling the trophic structure of marine food webs. Ecol. Lett. 17, 239–250.

Jenkins, S.G., Partridge, S.T., Stephenson, T.R., Farley, S.D., Robbins, C.T., 2001. Nitrogen and carbon isotope fractionation between mothers, neonates, and nursing offspring. Oecologia 129, 336–341.

Jochim, M.A., 2011. The Mesolithic. In: Milisauskas, S. (Ed.), European Prehistory. Springer, New York, pp. 115–142.

Johansson, A.D., 2006. Maglemosekulturens fiskepladser i Köng Mose og Barmose, Sydsjälland. In: Eriksen, B.V. (Ed.), Stenaldersstudier. Tidligt mesolitiske jaegere og samlere i Sydskandinavien. Jysk Arkeologisk Selskab, Århus, pp. 119–134.

Katzenberg, M.A., Weber, A., 1999. Stable isotope ecology and palaeodiet in the Lake Baikal region of Siberia. J. Archaeol. Sci. 26, 651–659.

Katzenberg, M.A., Goriunova, O., Weber, A., 2009. Paleodiet reconstruction of Bronze Age Siberians from the mortuary site of Khuzhir-Nuge XIV, Lake Baikal. J. Archaeol. Sci. 36, 663–674.

Kelly, R.L., 2013. The Lifeways of Hunter-Gatherers: The Foraging Spectrum. Cambridge University Press, Cambridge.

Kjällquist, M., Boethius, A., Emilsson, A., 2016. Norje Sunnansund: boplatslämningar från tidigmesolitikum och järnålder: särskild arkeologisk undersökning 2011 och arkeologisk förundersökning 2011 och 2012, Ysane socken, Sölvesborgs kommun i Blekinge län. Blekinge Museum, Karlskrona.

Kullander, S., Nyman, L., Jilg, K., Delling, B., 2012. Ryggsträngsdjur. Strålfeniga fiskar. Chordata: Actinopterygii. SLU, Uppsala.

Lidén, K., 1996. A dietary perspective on Swedish hunter-gatherer populations. Laborativ Arkeologi 9, 5–23.

Lindqvist, C., Possnert, G., 1999. The first seal hunter families on Gotland. On the Mesolithic occupation in the Stora Förvar cave. Current Swedish Archaeology 7, 65–88.

Lougheed, B.C., Filipsson, H.L., Snowball, I., 2013. Large spatial variations in coastal 14C reservoir age-a case study from the Baltic Sea. Clim. Past 9, 1015.

McCutchan, J.H., Lewis, W.M., Kendall, C., McGrath, C.C., 2003. Variation in trophic shift for stable isotope ratios of carbon, nitrogen, and sulfur. Oikos 102, 378–390.

Milner, N., Craig, O.E., Bailey, G.N., Pedersen, K., Andersen, S.H., 2004. Something fishy in the Neolithic? A re-evaluation of stable isotope analysis of Mesolithic and Neolithic coastal populations. Antiquity 78, 9–22.

Munthe, H., Hansson, H., 1930. En ny boplats från äldre stenåldern på Gotland. Fornvännen 1930, 257–285.

O'Connell, T., Kneale, C., Tasevska, N., Kuhnle, G., 2012. The diet-body offset in human nitrogen isotopic values: a controlled dietary study. Am. J. Phys. Anthropol. 149, 426–434.

Olson, C., Walther, Y., 2007. Neolithic cod (*Gadus morhua*) and herring (*Clupea harengus*) fisheries in the Baltic Sea – in the light of fine-mesh sieving. A comparative study of subfossil fish bone from the late stone age sites at Ajvide, Gotland, Sweden and Jettböle, Åland, Finland. Environ. Archaeol. 12, 175–185.

Österholm, I., 1989. Bosättningmönstret på Gotland under stenåldern. Theses and Papers in Archaeology 3, Stockholm.

Payne, S., 1972. Partial recovery and sample bias: the results of some sieving experiments. In: Higgs, E. (Ed.), Papers in Economic Prehistory. Cambridge University Press, Cambridge, pp. 49–63.

Persson, C., 2012. Den hemliga sjön—en resa till det småländska inlandet för 9000 år sedan. Göteborg: Gotarc series B(58) Gothenburg Archaeological Thesis.

Philippsen, B., 2012. Variability in Freshwater Reservoir Effects. Implications for Radiocarbon Dating of Pottery and Organisms From Estuarine Environments. (PhD thesis) Aarhus University, Aarhus.

Philippsen, B., 2013. The freshwater reservoir effect in radiocarbon dating. Heritage Science 1, 1–19.

Pira, A., 1926. On bone deposits in the Cave Stora Förvar on the Isle of Stora Karlsö, Sweden. Acta Zool. 7, 123–217.

Price, T.D., 2015. Ancient Scandinavia: An Archaeological History from the First Humans to the Vikings. Oxford University Press, New York.

Risberg, J., Alm, G., Björck, N., Guinard, M., 2007. Synkrona paleokustlinjer 7000–4000 kal. BP. In: Stenbäck, N. (Ed.), Stenålder i Uppland. Uppdragsarkeologi och eftertanke. Arkeologi E4 Uppland, Uppsala, pp. 99–136.

Rowley-Conwy, P., 1993. Season and reason: the case for a regional interpretation of Mesolithic settlement patterns. Archeological Papers of the American Anthropological Association 4, 179–188.

Schmitt, L., Larsson, S., Burdukiewicz, J., Ziker, J., Svedhage, K., Zamon, J., Steffen, H., 2009. Chronological insights, cultural change, and resource exploitation on the west coast of Sweden during the Late Palaeolithic/Early Mesolithic transition. Oxf. J. Archaeol. 28, 1–27.

Schmölcke, U., Meadows, J., Ritchie, K., Bērziņš, V., Lübke, H., Zagorska, I., 2015. Neolithic fish remains from the freshwater shell midden Riņņukalns in northern Latvia. Environ. Archaeol. 1–14.

Schnittger, B., Rydh, H., 1940. Grottan Stora Förvar på Stora Karlsö. Wahlström & Widstrand, Uppsala.

Segerberg, A., 1999. Bälinge mossar. Kustbor i Uppland under yngre stenåldern. Uppsala: Aun 26.

Seving, B., 1986. Tre mesolitiska boplatser på Gotland. Ett försök till tolkning av relation och lokaliseringsmönster. (Bachelor Thesis) Stockholm University, Stockholm.

Sponheimer, M., Robinson, T., Ayliffe, L., Roeder, B., Hammer, J., Passey, B., West, A., Cerling, T., Dearing, D., Ehleringer, J., 2003. Nitrogen isotopes in mammalian herbivores: hair δ15N values from a controlled feeding study. Int. J. Osteoarchaeol. 13, 80–87.

Storå, J., 2001. Skeletal development in the grey seal *Halichoerus grypus*, the ringed seal *Phoca hispida* botnica, the harbour seal *Phoca vitulina* and the harp seal *Phoca groenlandica*. Epiphyseal fusion and life history. In: Pike-Tay, A. (Ed.), Assessing Season of Capture, Age and Sex of Archaeofaunas. ArchaeoZoologia, XI, pp. 199–222.

Storå, J., 2002. Neolithic seal exploitation on the Åland Islands in the Baltic Sea on the basis of epiphyseal fusion data and metric studies. Int. J. Osteoarchaeol. 12, 49–64.

Terberger, T., Gramsch, B., Heinemeier, J., 2012. The underestimated fish? Early Mesolithic human remains from Northern Germany. In: Niekus, M.J.L., Barton, R.N.E., Street, M., Terberger, T. (Eds.), A Mind Set on Flint. Groningen University Library, Barkhuis.

Vanderklift, M.A., Ponsard, S., 2003. Sources of variation in consumer-diet δ15N enrichment: a meta-analysis. Oecologia 136, 169–182.

Wallin, P., Sten, S., 2007. Säljakten på Gotland. Gotländskt Arkiv 23–40.

Welinder, S., 1978. The “concept” of ecology in Mesolithic research. In: Mellars, P. (Ed.), The Early Postglacial Settlement of Northern Europe. Duckworth, London, pp. 11–25.

Supplementary material: The importance of freshwater fish in Early Holocene subsistence: exemplified with the human colonization of the island of Gotland in the Baltic basin

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AMS dates

Table S1. AMS dates from Gisslause, Stora Bjärs and the Stora Förvar cave sequence, all dates given as original uncalibrated bp values.

Lab. no.	bp value	Site	SD	13C	Species	References
LuS-12056	8160	Stora Förvar	45	ND	Pike	This paper
LuS-12058	8125	Stora Förvar F12	50	ND	Pike	This paper
LuS-12057	8105	Stora Förvar F12	50	ND	Pike	This paper
Ua-4955	8020	Stora Förvar G9	80	-20.05	Pike	This paper*
LuS-12055	8075	Stora Förvar	45	ND	Salmon	This paper
Ua17171	7765	Stora Förvar G10	80	-18.9	Salmon	This paper*
Ua-4192	7315	Stora Förvar G9	85	-18.23	Salmon	This paper*
LuS-12039	7975	Stora Förvar PG3 L5	45	ND	Salmon	This paper
Ua-3132	8555	Stora Förvar G10	135	-19.2	Human	Lindqvist & Possnert (1999:table 2)
Beta-399029	8420	Stora Förvar 2013	40	-17.7	Human	Apel et al. (2017)
Ua-13555	8380	Stora Förvar G9	85	-18.1	Human	Lindqvist & Possnert (1999:table 2)
Ua-13554	8360	Stora Förvar G10	95	-18.9	Human	Lindqvist & Possnert (1999:table 2)
Ua-17183	8345	Stora Förvar G8	85	-19.7	Human	This paper*
Ua-3789	8340	Stora Förvar G8	100	-18.9	Human	Lindqvist & Possnert (1999:table 2)
Ua-386399	8330	Stora Förvar F13	40	-19.3	Human	This paper
Ua-17181	8285	Stora Förvar G8	85	-19.2	Human	This paper*
Ua-2918	8270	Stora Förvar G11	75	-19.2	Human	Lindqvist & Possnert (1999:table 2)
Beta-399027	8260	Stora Förvar F9	30	-18.8	Human	This paper
Ua-17180	8260	Stora Förvar G10	105	-19.5	Human	This paper*
Ua-13407	8260	Stora Förvar G10	95	-18.4	Human	Lindqvist & Possnert (1999:table 2)
Ua-3788	8220	Stora Förvar G10	95	-18	Human	Lindqvist & Possnert (1999:table 2)
Beta-448533	8220	Stora Förvar F11	30	-19.1	Human	This paper
Beta-448531	8080	Stora Förvar F12	30	-16.4	Human	This paper
Beta-448532	8070	Stora Förvar F11	30	-16.7	Human	This paper
Ua-17182	8030	Stora Förvar G8	80	-20	Human	This paper*
Ua-45741	7952	Stora Förvar A12-14	53	-17.5	Human	Skoglund et al 2014
Ua-13406	7830	Stora Förvar	90	-17.7	Human	Lindqvist & Possnert (1999:table 2)
Ua-2930	7440	Stora Förvar	85	-17.7	Human	Lindqvist & Possnert (1999:table 2)
Ua-2929	8260	Stora Förvar G9	110	-18.67	Seal	This paper*
Ua-2935	8255	Stora Förvar G8	120	-20.79	Seal	bone+tooth, Tandem Lab., Uppsala
Ua-2936	8200	Stora Förvar G8	105	-19.11	Seal	This paper*
Ua-2928	8145	Stora Förvar G9	110	-19.08	Seal	This paper*
Ua-17173	8130	Stora Förvar G8	90	-20	Seal	This paper*
Beta-399028	8100	Stora Förvar 2013 PG3, l4	30	-19.6	Seal	Apel et al. (2015)
Beta-399030	8100	Stora Förvar 2013	30	-18.9	Seal	Apel et al. (2015)
Ua-17177	7670	Stora Förvar G10	120	-20	Seal	This paper*
Ua-2921	8200	Stora Förvar G11	125	-20.5	Hare	This paper*
Ua-42934	8100	Stora Förvar SF5	51	-21.9	Hare	Ahlgren (2011)
Ua-2931	8065	Stora Förvar G8	105	-20.67	Hare	This paper*
Ua-42931	8014	Stora Förvar SF2	57	-22.2	Hare	Ahlgren (2011)
Ua-42932	8010	Stora Förvar SF3	46	-21.2	Hare	Ahlgren (2011)
Ua-53424	7966	Stora Förvar F13	35	-24.6	Hazelnut	This paper
Ua-17166	7825	Stora Förvar G10	70	-21.4	Hare	This paper*
Ua-2937	7795	Stora Förvar G8	105	-25	Hazelnut	This paper*
Beta-449544	7480	Stora Förvar F13	30	-24,8	Hazelnut	This paper
Ua-49233	7192	Stora Förvar SF4	45	-22	Hare	Ahlgren (2011)
Ua-42849	7988	Gisslause	44	-27.2	Hazelnut	Apel & Vala (2013)
Ua-42850	7926	Gisslause	42	-27.2	Hazelnut	Apel & Vala (2013)
Ua-4957	7860	Gisslause	100	-20.35	Seal	This paper*
Ua-42935	7747	Gisslause	209	-23	Hare	Ahlgren (2011)
Ua-42929	7572	Gisslause	128	-24	Hare	Ahlgren (2011)
St-9059	7265	Gisslause	75	ND	Charcoal	Seving (1986)
LuS-11860	6490	Gisslause	70	-17.43	Cyprinid	This paper (Not reliable)
LuS-11858	6250	Gisslause	60	-16.71	Cyprinid	This paper (Not reliable)
Ua-45911	5965	Gisslause	40	-16.8	Pike	This paper (Not reliable)
LuS-11859	5865	Gisslause	80	-18.54	Perch	This paper (Not reliable)
LuS-12038	5615	Gisslause	75	ND	Burbot	This paper (Not reliable)
LuS-11857	5600	Gisslause	65	-19.91	Pike	This paper (Not reliable)
LuS-11861	5365	Gisslause	70	-19.87	Burbot	This paper (Not reliable)
LuS-11862	4925	Gisslause	80	-22.17	Burbot	This paper (Not reliable)
Ua-45912	3245	Gisslause	35	-17.2	Cyprinid	This paper (Not reliable)
Ua-46146	7711	Stora Bjärs	51	-20.7	Red deer	Apel & Storå (2017)
Ua-46147	7974	Stora Bjärs	49	-16.1	Human	Apel & Storå (2017)

The dating of fish bones at Gisslause

In order to understand the chronology at Gisslause, a set of 15 samples was submitted for ^{14}C dating (Figure S.1). This was done in three stages, following an inconsistency in the material whereby the fish bone dates were much younger than all the other elements from the site. Initially, given the geology and other find circumstances, we were unable to explain or understand this. However, after a deeper analysis we could account for the inconsistencies. When the C:N atomic ratio of the fish bones was examined, all except one gave values outside the accepted range of 2.9-3.6 (DeNiro 1985). Furthermore, the only sample that fell within the accepted range exhibited a very low content of both carbon (3.7%) and nitrogen (1.4%). The actual $\delta^{13}C$ and the $\delta^{15}N$ isotope values were within expected ranges but the analyses were done in a different laboratory and on different equipment compared with the dating. Thus, the isotope value can probably be considered plausible, but not the radiocarbon date. This was examined further with a second set of fish bones, which were rigorously ultra-filtered. However, no uncontaminated collagen could be collected from the filter, and when we decided to date the contaminated remains from the filtration (the part normally discarded) it also gave a younger date and an atomic C:N ratio outside the accepted range, proving that the fish bones had suffered from diagenetic alteration and that any AMS dates from them were unreliable. That only the fish bones at Gisslause seem to have suffered from diagenetic processes in this way is probably associated with their more fragile and less dense structure compared with mammal bones (Wheeler & Jones 1989). This is because of the buoyant effect of the water, which negates the need for the fish skeleton to develop the strength and stability needed to cope with the force of gravity that affects terrestrial animals (Moyle & Cech 2004), as well as the generally smaller size of fish bones, which makes them more fragile compared with mammal bones.

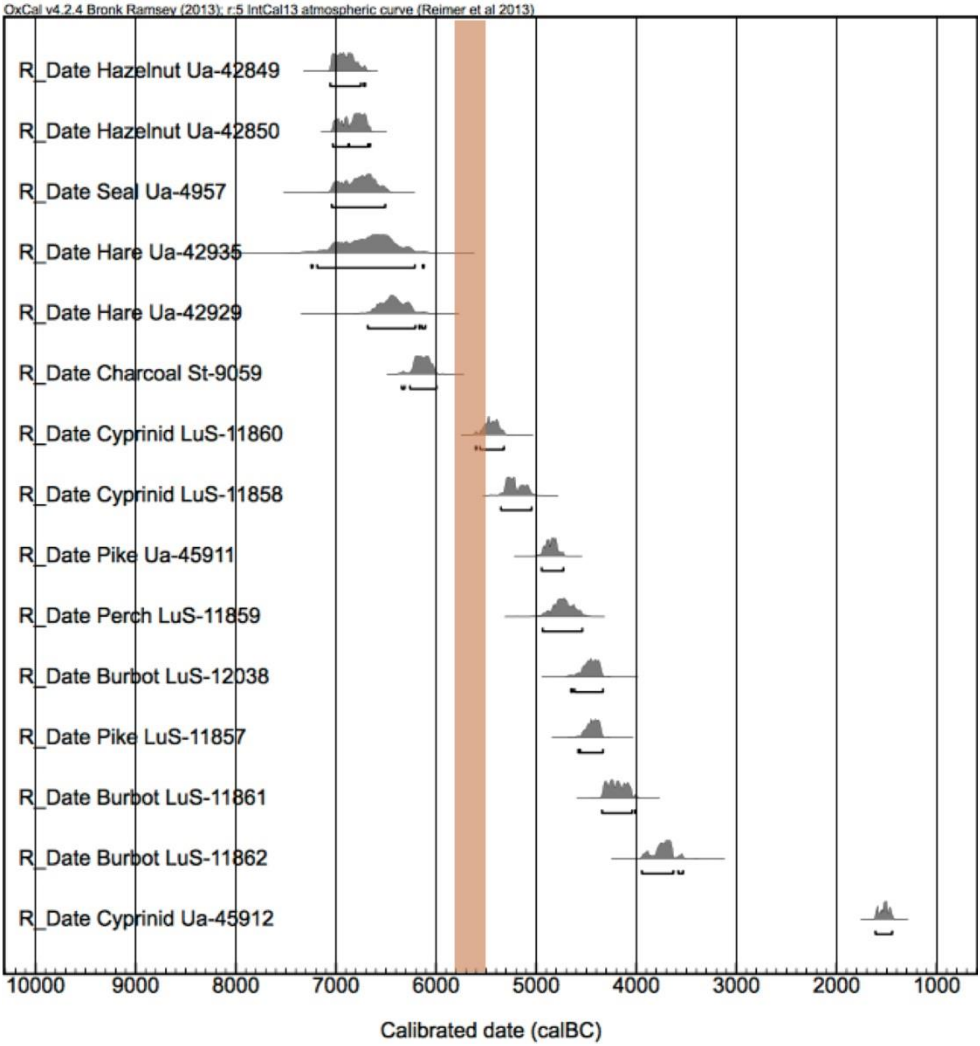

Figure S.1 ^{14}C dates from Gisslause. The site was covered by a 1-m thick layer of chalk gravel during the Littorina I transgression (yellow strip), which reached its maximum c. 7600 cal. BP (5600 cal. BC). Note that all dated fish bones from the closed cultural layer give younger dates, probably as a result of severe diagenesis.

References

Ahlgren H., 2011. On the origin of the mountain hare on the island of Gotland. By means of ancient DNA analysis. Master Thesis. Stockholm: Stockholm University.

DeNiro, M.J., 1985. Postmortem preservation and alteration of in vivo bone collagen isotope ratios in relation to palaeodietary reconstruction. Nature, 317, 806-809.

Moyle, P.B., Cech, J.J., 2004. Fishes: an introduction to ichthyology. 5th edition, Uppersaddle River, NJ, Prentice Hall.

Skoglund, P., Malmström, H., Omrak, A., Raghavan, M., Valdiosera, C., Günther, T., Sjögren, K.-G., Apel, J., Willerslev, E., Storå, J., Götherström, A., Jakobsson, M., 2014. Genomic diversity and admixture differs for Stone-Age Scandinavian foragers and farmers. Science, 344(6185), 747-750.

Wheeler, A., Jones, A.K., 1989. Fishes, Cambridge, Cambridge University Press.

Paper VI

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Fish and resilience among Early Holocene foragers of southern Scandinavia: A fusion of stable isotopes and zooarchaeology through Bayesian mixing modelling

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ABSTRACT

This study highlights the importance of different protein sources in the diet of Early and Middle Mesolithic humans in southern Scandinavia, and illustrates variation and change in protein consumption patterns during the Early Holocene. By combining previously published stable isotope data with new analyses of human and animal bone remains, a Bayesian mixing model was used to reveal that fishing was more important than previously anticipated in the foraging economy. Incorporating the zooarchaeological record as a prior to guide the Bayesian model enabled further study of Early Holocene foraging in the region. Although primarily a study of human diet, because the results indicate that aquatic systems were more important than previously acknowledged, it is possible to discuss the implications for understanding Early Holocene subsistence strategies and mobility. Furthermore, by incorporating both zooarchaeological data and human stable isotope analysis, the methodology can advance palaeodietary studies, by generating dietary protein estimations that can be used to investigate subsistence strategies across a diverse set of human societies.

1. Introduction

The forager lifeway (hunting, gathering and fishing as the main base of subsistence) is the oldest human subsistence strategy, providing a versatile diet that can be adapted to almost every type of environment. In southern Scandinavia, foragers were present from around 14,000 (Riede, 2014) to at least 6000 years ago (Sørensen and Karg, 2014). Although forager subsistence is based on a combination of hunting, gathering and fishing, archaeological evidence emphasizes hunting in the Early Holocene, based on animal bone frequencies (Aaris-Sørensen, 1976; Blankholm, 1996; Jochim, 2011; Larsson, 1982; Leduc, 2012; Rosenlund, 1980; Sarauw, 1903). The perceived predisposition towards terrestrial mammals on mainland Scandinavia is probably related to the limited quantities of fish bones found in Scandinavian Early Mesolithic contexts. In addition, fish traps are traditionally made of organic material, e.g. wood (Hansson et al., 2018; Pedersen, 1995), which rarely survives into the archaeological record, whereas traditional hunting equipment, such as arrow tips and microliths, e.g. as found in the Prejlerup aurochs (Aaris-Sørensen and Petersen, 1986), is made of materials that survive more readily.

Ichthyo-archaeological remains are affected by preservation bias, i.e. fish bones are small, fragile and more susceptible to diagenesis than mammal bones (Moss, 1961; Wheeler and Jones, 1989), and may not be preserved at archaeological sites, even if bones from other taxa appear in abundance. In addition, fish bones require special field-recovery techniques, i.e. fine mesh sieving, in order to be revealed (Enghoff, 2007, 2011; Hultgreen et al., 1985; Payne, 1972). Fish bones therefore tend to be underrepresented at archaeological sites.

Within Scandinavian Mesolithic research, a large marine fish dietary input was demonstrated in the early 1980s, associated with human remains from the Late Mesolithic Ertebølle culture (Tauber, 1981). Marine isotope signals, indicating a diet based on marine mammals and fish, have also been demonstrated for the Early Mesolithic, from humans on the west coast of Sweden (Eriksson, 2003). However, because of the transgression following the last ice age, almost all of the European Atlantic coastline from the Early Mesolithic is now submerged and, as a consequence, any coastal settlement occupied by humans during the Early Mesolithic is now under water and inaccessible to 'standard' archaeological

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excavations. In addition, the complex evolution of the Baltic Sea has forced humans to adapt over time to different aquatic ecosystems. The Baltic Sea existed first as a freshwater ice lake connected to the melting glaciers (the Baltic ice lake), then as a marine sea connected to the Atlantic Ocean (the Yoldia Sea). This was followed by a closed-off freshwater lake stage (the Ancylus Lake) and, finally, at the end of the Mesolithic, the Littorina Sea (Andrén et al., 2011; Björck, 1995), with similar characteristics as today but with higher salinity levels and greater temporal salinity flux (Emeis et al., 2003).

The entire Baltic Sea during the Early Mesolithic was freshwater, with a non-existent or very low saline influence (Andrén et al., 2011); any fish living within it would have been freshwater fish, yielding freshwater isotope signals. As a result of the transgression and subsequent shifts in the coastline, the majority of human remains from the Early and Middle Mesolithic have been found in inland freshwater environmental contexts and display lower marine signals compared with humans from the Late Mesolithic (Fischer et al., 2007), for which coastal sites are available for study and by which time the Baltic Sea had become saline. Therefore, most human remains from the Early and Middle Mesolithic period originate from freshwater environmental contexts. However, the combination of almost exclusively inland Early Mesolithic settlements [with only summer seasonal indicators (Carter, 2001; Rowley-Conwy, 1993, 1999)], fish bone taphonomy, a lack of large-scale fine-mesh sieving on previously excavated Early Holocene Scandinavian sites, and difficulties in demonstrating a freshwater fish diet through stable isotope analysis (see the Methods: Bias against freshwater fish consumption), means it has been difficult to recognize a dietary freshwater fish influence.

Early Mesolithic freshwater fish exploitation has become less intangible with the recovery of large quantities of fish bones from the Early Mesolithic settlement of Norje Sunnansund, in south-eastern Sweden (Boethius, 2016a, 2017, 2018b), which also included evidence of fermentation as a means of conserving the fish and storing it for later consumption (Boethius, 2016b). The findings from Norje Sunnansund were facilitated by good preservation and the use of fine-mesh water sieving on a large scale, which had not been carried out previously on contemporaneous sites. The evidence of human reliance on freshwater fish, from the only known Early Mesolithic Baltic Sea coastal settlement, from mainland Scandinavia, with preserved organic remains, which also displays year-round seasonality indicators (Boethius, 2017), raises the question of how well we understand the importance of fish during the Early and Middle Mesolithic, and to what extent these finds can be said to reflect a general Early Holocene Scandinavian subsistence.

Refinements of stable isotope fractionation factors (see the Methods), from prey to consumer, and the combination of new data and Bayesian mixing models have enabled a review of fish in past human diet at a broad scale, and made the study of subsistence strategies throughout Early and Middle Mesolithic Scandinavia (11,500–7500 cal. BP) possible. Although primarily a study on human diet, the findings presented here are discussed within a broader context and are used to address both temporal and spatial dietary trends from a general, large-scale, perspective, to a context-specific, settlement-orientated, perspective. The aim is to elucidate whether source-specific dietary estimations can enhance our understanding of Early Holocene diet and subsistence in southern Scandinavia and, if so, what the implications are.

2. Materials and methods

2.1. Isotope data

The dietary stable isotopes $\delta^{13}C$ and $\delta^{15}N$ were analysed, based on the extraction of collagen from southern Scandinavia Early Holocene human individuals ($n = 82$) and their potential food sources ($n = 323$) (Fig. 1).

Isotope data were collected by sampling and extracting collagen from 419 bones from Mesolithic contexts in southern Scandinavia. Of the 419 samples, a total of 186 were selected for use in the study; the remaining results were discarded because of suspected contamination (see Collagen extraction) or because they belonged to unincorporated dietary sources (e.g. dogs). An additional 192 isotope values were collected from previously analysed Mesolithic samples (Borrman et al., 1995; Eriksson, 2003; Eriksson et al., 2016; Fischer et al., 2007; Fornander, 2011; Lidén, 1996; Robson et al., 2012, 2016; Sjögren and Ahlström, 2016; Sten et al., 2000). Of the 378 usable bone samples from Scandinavian Mesolithic sites, 82 were from humans (see Supplementary Data (SD) 1). The other 296 samples (see SD2 and SD3) were from 11 categories of animals. In addition, the isotope values from the Mesolithic animal bones were combined with the values from one mushroom sample and three selected plant groups [represented by 27 individual isotope samples extracted from modern plants in Białowieza, a primeval forest in eastern Poland (Selva et al., 2012)], in order to estimate isotopic baselines (Table 1).

The use of plants and mushrooms from Białowieza was motivated by the fact that most plant material, similar to animal soft tissues, does not survive in archaeological contexts. Although seeds and nut shells from a few plant species do sometimes survive, the isotopic offset between plant ‘flesh’ and plant shells or seeds has not been studied as well as the offset between animal soft tissue and bones, and thus the link between seeds and less hardy plant material is uncertain. The Białowieza forest was chosen as a source for the plant and mushroom material because it is the closest and largest available forest to the study area, and has restrictions regarding modern-day access. The effects of soil fertilizers and modern industrial pollution, such as CO_2 emissions, should be minimal within Białowieza. Local CO_2 emissions have the largest effect on $\delta^{13}C$ values (Pawełczyk and Pazdur, 2004:717), and Białowieza is considered to be a relatively ‘clean’ zone. In order to account for changes in global atmospheric carbon isotope composition, i.e. changes in atmospheric $\delta^{13}C$ caused by admixture of fossil fuels (the Suess effect), 2‰ were added to the $\delta^{13}C$ values for the plants and mushrooms from Białowieza, as suggested by a comparison between 9000-year-old air bubbles trapped in an ice core from Antarctica (Indermühle et al., 1999) and recent atmospheric CO_2 measurements from Antarctic air, collected the same year and the year after the material from Białowieza was gathered (Longinelli et al., 2013).

When all the acceptable isotope data had been collected, the species providing the dietary protein baselines were divided into the different source groups and the mean value and standard deviation calculated for each source (Table 1). The animal dietary sources originated from various archaeological contexts throughout southern Scandinavia and were all of Mesolithic origin. No temporal or spatial resolution was attempted to divide the dietary sources into subgroups, because the aim was to study protein dietary trends across the human populations and a more general baseline was needed to enable evaluation of the human isotope signals. In some respects this approach was not optimal, e.g. $\delta^{13}C$ values of aquatic animals have been shown to vary greatly between different freshwater ecosystems (Grey et al., 2000; Milner et al., 2004) and terrestrial animals can also show some spatial and temporal variation in stable isotope values as a result of climate, latitude, temperature, level of canopy cover, etc., i.e. local environment (Van Klinken et al., 2000), which will reduce the precision of the estimated models. However, the use of general baselines was necessitated by the lack of sufficient available source data from any

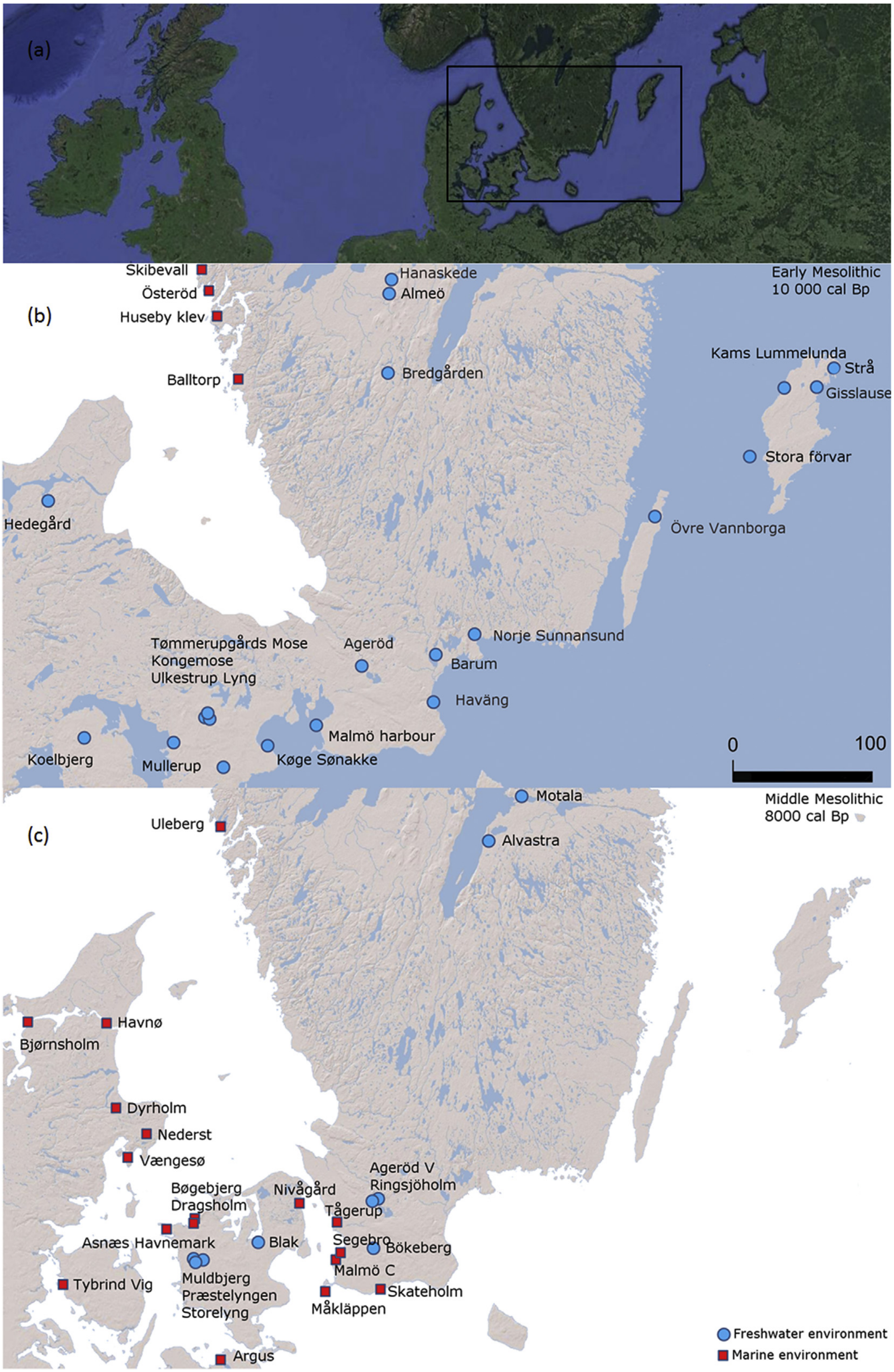

Fig. 1. Map indicating the location of the archaeological sites contributing to the baseline or human stable isotope values. (a) The overall study area. (b) The Early Mesolithic sites with the approximate shoreline displacement around 10,000 cal. BP; (c) the Middle and Late Mesolithic sites with approximate shoreline displacement around 8000 cal. BP. (a) from Google Earth (2016) (Data: SIO, NOAA, US Navy, NGA, GEBCO); (b, c) shoreline displacement maps created by using information from Swedish Geological Survey (SGU) and Påsse & Andersson's calculations (2005).

Table 1
The dietary sources used to provide isotopic baseline data, with mean stable δ^{13}C and δ^{15}N values and standard deviations (Std). *Species and families only contributing to the prior (Table 2) and not to the isotopic baselines. †Plant and mushroom δ^{13}C values with an added 2‰ to account for the Suess effect. Indet., indeterminable species.

Source	Species included in category	Code name	Mean δ^{13}C	Std δ^{13}C	Mean δ^{15}N	Std δ^{15}N	*N*
Terrestrial herbivores	Elk (*Alces alces*), Red deer (*Cervus elaphus*), Roe deer (*Capreolus capreolus*), Aurochs (*Bos primigenius*), Beaver (*Castor fiber*), Mountain hare (*Lepus timidus*), Cervidae indet.*	THE	−22.21	0.95	4.07	1.23	77
Terrestrial omnivores	Wild boar (*Sus scrofa*), Brown bear (*Ursus arctos*), Hedgehog (*Erinaceus europaeus*)	TOM	−21.41	1.12	5.16	1.17	48
Freshwater aquatic mammals	Grey seal (*Halichoerus grypus*), Ringed seal (*Pusa hispida*), Phocidae indet.*	FAM	−19.54	0.53	11.66	0.92	28
Marine aquatic mammals	Grey seal (*Halichoerus grypus*), Harbour seal (*Phoca vitulina*), Harp seal (*Pagophilus groenlandicus*), Harbour porpoise (*Phocoena phocoena*), White-beaked dolphin (*Lagenorhynchus albirostris*), Dolphinidae indet.*, Phocidae indet.*	MAM	−14.43	1.77	15.74	1.86	25
Berries	Bilberry (*Vaccinium myrtillus*), Lingonberry (*Vaccinium vitis-idaea*)	BER	−30.2†	0.7	−5.7	0.5	6
Fruits	Raspberry (*Rubus idaeus*), Apple (*Malus* sp.), Bird cherry (*Prunus padus*), Edible currants (*Ribes* sp.)	FRU	−26.72†	1.25	0.58	2.57	5
Hazelnuts	Hazelnut (*Corylus avellana*)	HAZ	−30.6†	0.6	−0.6	0.4	10
Mushrooms	Mushrooms (Fungi)	MUS	−20.2†	0.3	−0.2	0.7	6
Pike	Northern pike (*Esox lucius*)	PIK	−19.29	5.74	9.08	1.54	29
Freshwater mid-trophic fish	Perch (*Perca fluviatilis*), Burbot (*Lota lota*), Zander (*Sander lucioperca*), Percidae indet.*, Smelt (*Osmerus eperlanus*)*, *Whitefish* (*Coregonus* sp.)*, *Arctic char* (*Salvelinus alpinus*)*, *Ruffe* (*Gymnocephalus cernua*)*	FMF	−21.39	5.22	8.28	1.71	15
Cyprinids	Bream (*Abramis brama*), Tench (*Tinca tinca*), Roach (*Rutilus rutilus*), Ide (*Leuciscus idus*), Cyprinids (Cyprinidae sp.)*	CYP	−17.66	3.20	5.63	1.32	15
Freshwater catadromous/anadromous fish	Eel (*Anguilla anguilla*), Trout (*Salmo trutta*)*, Salmon (*Salmo salar*)*, Salmonids (Salmonidae sp.)*	FCA	−19.11	2.43	8.21	1.48	5
Marine high-trophic fish	Cod (*Gadus morhua*), Ling (*Molva molva*), Spurdog (*Squalus acanthias*), Garfish (*Belone belone*)	MHF	−12.01	2.13	11.02	1.27	21
Marine low-trophic fish	Flounder (*Pleuronectidae* sp.), Atlantic mackerel (*Scomber scombrus*)	MLF	−13.66	2.66	9.26	2.59	11
Marine catadromous/anadromous fish	Eel (*Anguilla anguilla*), Salmonids (Salmonidae sp.)	MCA	−9.98	2.09	8.72	1.08	22

specific site, and it has the advantage of not excluding mobility-dependent factors, i.e. dietary sources divergent from local baselines. When a larger database of dietary source material becomes available in the future, it will be possible to model human diets from exclusively local sources.

The sources were selected pragmatically to include plausible major dietary groups. The plant sources were added to incorporate low-trophic protein sources; the consumption of carbohydrates cannot be indicated easily by collagen-derived isotopes. Birds and terrestrial carnivores were not included because of insufficient collagen samples to build a representative baseline. Their omission was considered acceptable because of their apparently low dietary importance, as indicated by low bone frequencies at Scandinavian Mesolithic sites combined with a relatively high species abundance, suggesting opportunistic hunting (Boethius, 2017). Additionally, terrestrial carnivores are often considered to have been caught mainly for their pelts, rather than as a source of food. Birds can present a large baseline variation because of differences in life histories and diet between different species, which would confound the output of the mixing model, especially if each of the different bird species had limited importance to the overall protein intake.

2.2. Classifying the Mesolithic foragers

Each human skeleton included in the study was classified according to time period (Early or Middle Mesolithic) and context (freshwater, i.e. inland or along the Baltic Sea coast during the Early Mesolithic period, or marine, i.e. on the west coast of Scandinavia or along the south-western coast of the Baltic Sea during the Middle Mesolithic period). The need to separate human isotope values according to context is important, otherwise sources that are non-existent in certain contexts will be added into the model. A strict contextual classification was used, even though humans are capable of travelling between inland and coastal sites and can therefore consume both freshwater and marine fish and seals. As there were no indications of freshwater fish input (no identified bones) at marine coastal settlements, nor any marine fish species at the inland sites, and because context-specific aquatic mammal bone samples were used to create the freshwater aquatic mammal (FAM) and marine aquatic mammal (MAM) baselines, this approach was deemed optimal. The decision was further justified by the low frequency of $\delta^{13}C$ and $\delta^{15}N$ value overlap between humans from freshwater and marine contexts (Fig. 2d), which suggested that the Mesolithic humans mainly subsisted on a local protein diet. Even though some individuals from the different contexts may have had some level of dietary input from the other contexts, e.g. some freshwater fish were eaten by humans buried in a marine setting and vice versa, in general it was not enough to cause overlapping human isotope signals between the contexts. While seals, for example, from freshwater contexts show distinct isotopic differences compared with seals from marine contexts, it is difficult to determine the fractionation between freshwater fish and freshwater seal, because they do not match. This is probably because the freshwater fish found in the archaeological settings were not from the same fish populations that the seals were eating, i.e. humans probably ate freshwater fish caught in rivers and lakes while seals probably ate fish caught in the Baltic Sea (consequently the Baltic Sea fish stable isotope values are unavailable for study). This highlights the need to be able to disentangle the isotope signals from multiple dietary sources when interpreting human stable isotope signals.

2.3. *Bias against freshwater fish consumption*

Since the late 1970s, the study of stable isotopes in human skeletal material has been used to analyse the diet of prehistoric societies (Ambrose and DeNiro, 1986; DeNiro and Epstein, 1981; Tauber, 1981). However, one difficulty when studying the palaeodiet of humans is recognizing a large freshwater fish input (Hedges and Reynard, 2007). There are many reasons why freshwater fish consumption is difficult to detect, a crucial one being the wide ranges of $\delta^{13}C$ and $\delta^{15}N$ values that occur. In turn, there are many reasons for these wide ranges, such as the trophic state of the lake and the subsequent variation in $\delta^{13}C$ stable isotope values within the phytoplankton in each lake (Grey et al., 2000), which has an effect on the values from the fish eating the plankton, and the animals eating the fish. Different freshwater ecosystems have been shown to display often unique chemical compositions, resulting in variations in $\delta^{13}C$ values between, for example, different estuaries (Milner et al., 2004). $\delta^{13}C$ values have also been shown to vary within a lake (Hecky and Hesslein, 1995), which means isotope signals can vary depending on where in the lake and at what depth each individual fish or species lives (Katzenberg et al., 2009; Katzenberg and Weber, 1999).

$\delta^{15}N$ values are often used to separate a terrestrial diet from a marine diet, but there are also confounding issues with stable nitrogen isotope signals. Because a marine food chain is longer than a terrestrial food chain, and the amount of ^{15}N in an animal increases with each prey–consumer stage in a food chain, $\delta^{15}N$ values are elevated in humans consuming large amounts of marine food. The food chain is shorter in freshwater ecosystems than in marine ecosystems (Cohen, 1994), which results in lower $\delta^{15}N$ values in humans living on a freshwater diet compared with humans living on a marine diet (Katzenberg, 1989). There is also a latitude-dependent difference in food chain length, with a diminished aquatic species abundance at higher latitudes (Wheeler and Jones, 1989), resulting in less elevated $\delta^{15}N$ values in fish living at higher latitudes. In addition, some potentially large and common freshwater fish species (cyprinids) live at a lower trophic level diet, e.g. consuming plankton, invertebrates, algae and plant debris (Weatherley, 1987), and as a consequence can themselves be considered to inhabit a lower trophic level niche (Vander Zanden et al., 1997). At Scandinavian latitudes, cyprinids display similar or only slightly higher $\delta^{15}N$ values compared with terrestrial herbivores and omnivores, e.g. compare cyprinid $\delta^{15}N$ values with the values obtained from terrestrial mammals in Fischer et al. (2007) and Schmölcke et al. (2016), which makes it difficult to separate a human diet based on cyprinids from a diet based on terrestrial mammals.

2.4. *Deriving stable isotope fractionation factors*

A potentially biasing factor, when working with human forager stable isotope signals, is that the fractionation factors of both stable carbon isotopes, $\Delta^{13}C$, and stable nitrogen isotopes, $\Delta^{15}N$, vary depending on environmental context (terrestrial, marine or freshwater), taxonomy, trophic level, metabolic rate, tissue and quality of diet (Dalerum and Angerbjörn, 2005; Florin et al., 2011; McCutchan et al., 2003; Vanderklift and Ponsard, 2003). During the last decade, studies in ecology have stressed the importance of applying the correct fractionation factor when studying stable isotopes, and have demonstrated large variations given different premises (Caut et al., 2008, 2009; Hussey et al., 2014). Caut et al. (2009) present different regression equations for calculating the $\Delta^{15}N$ for a number of taxonomic groups and particular body tissues. However, these have in turn been criticized as biased (Auerswald et al., 2010; Codron et al., 2012; Perga and Grey, 2010). Because of the many factors involved in the diet to consumer stable isotope fractionation rate, it has been considered the largest source of uncertainty when using mixing models to assess diet (Phillips et al., 2014). One solution, when working with sources with unspecified fractionation, is to apply a standard deviation to set fractionation factors (Phillips et al., 2014). We used average $\Delta^{13}C$ and $\Delta^{15}N$ values and increased the standard deviation to account for unknown discrepancies. Regarding $\Delta^{13}C$, recent studies have shown fractionation factors of up to 4.8‰ (Fernandes et al., 2012). However, because they were applied uniformly on all sources, we used two sets of 'standard' source-specific $\Delta^{13}C$ rates, one for plant soft tissues to human collagen and one for animal bone collagen to human collagen (Malainey, 2011). $\Delta^{13}C_{\text{plant–human collagen}}$ was set to 5‰± 0.9, and $\Delta^{13}C_{\text{animal collagen–human collagen}}$ was set to 1‰±0.9.

$\Delta^{15}N$ fractionation is more complicated because large and inconsistent fractionation factor variations have been noted (Ambrose, 2000; Bocherens and Drucker, 2003; Caut et al., 2008, 2009; Hussey et al., 2014; Jenkins et al., 2001; O'Connell et al., 2012; Sponheimer et al., 2003), which renders the originally suggested $\Delta^{15}N$ of 3‰ (DeNiro and Epstein, 1981; Schoeninger and DeNiro, 1984) obsolete. To account for the highly varied $\Delta^{15}N$, we estimated the $\Delta^{15}N$ offset to fall between the most commonly used fractionation factor in ecological studies, $\Delta^{15}N$ 3.4 (Minagawa and Wada, 1984; Post, 2002), and a recent study suggesting a diet–human $\Delta^{15}N$ of 6‰ (O'Connell et al., 2012). The fractionation factor for $\Delta^{15}N_{\text{all sources}}$ was set to 4.7‰±1.3, where the standard deviation catches fractionation factors between 3.4‰ and 6‰ and thus also encompasses variations in the offset between animal soft tissue and the bone collagen available for study.

2.5. Collagen extraction

Bulk collagen from different Scandinavian Mesolithic bone samples was used for the analysis of dietary protein input (Lee-Thorp et al., 1989). While it is possible to analyse compound-specific amino acids to obtain closer dietary estimates (Howland et al., 2003), this was not done because we wanted to explore the option of including older available samples as well as new extractions. However, compound-specific amino acids can, in the future, be incorporated into Bayesian mixing models to render even more detailed dietary estimations.

The human samples were almost all derived from bone collagen, and were selected to represent the diet of the last years of each individual's life. For five of the samples, from three individuals from Motala, one individual from Kongemose and one individual from Österöd, no stable isotope values from human bone collagen were available, so values from collagen that had been extracted from teeth were used instead. The latter values therefore represent the diet when the individuals were younger in age, when the tooth was being formed.

The collagen was extracted at Cornell University, Ithaca, USA (96 samples), Copenhagen University, Copenhagen, Denmark (314 samples), Lund University, Lund, Sweden (seven samples), and Chrono Laboratory at Queen's University, Belfast, UK (two samples). At Cornell University, the collagen was extracted according to a method adapted from Ambrose (1990), after first being cleaned with pressurized gas to blow away any loose contamination. However, after the first 96 collagen samples had been run for both $\delta^{13}C$ and $\delta^{15}N$ isotopes, it was clear that 71 of the 96 samples (74%) displayed a biased C:N atomic ratio (≥ 3.7, ≤ 2.9), indicating contamination (DeNiro, 1985). This level of contamination was considered too high, and a new extraction method was sought to minimize the level of contamination. The next 314 bone samples were extracted in the geological department at Copenhagen University, following the method originally developed by Longin (1971) and modified by Richards and Hedges (1999), and carried out as recommended by Jørkov et al. (2007) using the following methodology. 1) Weigh between 100 and 250 mg of crushed bone material and put in to vials. 2) Add 10 ml 1 M hydrochloric acid (HCl) to 2–3 cm from the edge of the vial and put the contents in a refrigerator overnight, or for at least 1.5–10 h until the reaction is complete (no further release of CO_2). 3) Rinse samples in Milli-q (Mq) water until neutral and then remove the rinsing water. 4) Gelatinize samples by adding drops of 1 M HCl until a pH level of 2.5 is reached. 5) Put the samples in a 70 °C heating cabinet for 24 h. 6) Put the samples through 10-μm filters and proceed with the filtrate (the material outside the filter). 7) Clean an ultrafilter (30 kDa) using 0.1 M sodium hydroxide (NaOH) and put in a centrifuge at 3000 revolutions per minute (rpm) for 20 min and rinse with Mq water twice. 8) Add the filtrate (from stage 6) to the ultrafilter. 9) Centrifuge the contents at 2500 rpm for 15 min and repeat until all of the filtrate has been added (the remaining sample is larger than 30 kDa). 10) Lift out the filter with the fluid inside and discard the remaining filtered fluid outside the filter. 11) Once the complete samples are filtered and all excess fluid removed, put the contents in new vials and freeze dry for 24–48 h. 12) Weigh the ultrafiltered collagen and send for mass spectrometry. This method yielded better results. Although the proportion of contaminated samples in the first run might have been caused by a larger proportion of fish bones, which are more likely than mammal bones to display collagen diagenesis or contamination, from the second run we managed to collect enough uncontaminated collagen for further analysis from 171 of the 314 (54%) samples.

The seven samples at Lund University were extracted using a method adapted from Brodie et al. (2011), but only two samples displayed a C:N ratio within the acceptable range. The two samples at Belfast were also dated, and extractions were made following Longin (1971), Brown et al. (1988) and Ramsey et al. (2004). All of the extracted collagen, except the two samples from Belfast, were run at the Cornell stable isotope laboratory using combustion analysis at 1000 °C on a Carlo Erba Elemental Analyzer (Italy), connected to a Thermo Scientific Delta V Isotope Ratio Mass Spectrometer (Germany). The two samples from Belfast were measured on a Delta V Advantage EA-IRMS. All samples were measured relative to the vPDB standard for $\delta^{13}C$ and the AIR standard for $\delta^{13}N$. To ensure instrumental accuracy and precision, a number of laboratory and international standards were analysed after every 10 samples. For these analytical sample runs, the overall standard deviation was 0.11‰ for $\delta^{13}N$ and 0.13‰ for $\delta^{13}C$, using the in-house standard internal MINK (animal). The instrument's ability to measure samples across a gradient of amplitude intensities was quantified using a chemical Methionine standard. Based on the results of these samples, the $\delta^{13}N$ values had a 0.36‰ error and the $\delta^{13}C$ had a 0.44‰ error associated with linearity. Isotope corrections were performed using a two-point normalization of all $\delta^{13}N$ and $\delta^{13}C$ data using two additional in-house standards. No check of consistency was performed via multiple measurements of the same specimen in the new data.

2.6. Statistical analysis

Human isotope data were summarized as descriptive statistics, and differences between Early Mesolithic and Middle Mesolithic samples were assessed by a two-sample *t*-test with unequal variances (see Table 3).

In ecology, stable isotope data are used to deduce features of community structure and isotopic niche width, and several measurements have been used to do this (cf. Newsome et al., 2007). Isotopic niche width encapsulates the area occupied by the investigated species in a space defined by the two isotopes. A relatively larger isotopic niche width within a specific context (here, humans in the Early and Middle Mesolithic periods) imply a more generalized foraging behaviour, involving a more diverse set of sources, compared with a relatively constrained isotopic niche width, with fewer sources implied. However, studies of isotopic niche width are based on Convex Hull methods that are sensitive to sample size (Jackson et al., 2011). Jackson et al. (2011) have developed a method that is based on ellipses and unbiased with respect to sample size, referred to as standard ellipse areas (SEA), which is therefore more appropriate for archaeological studies that can have small sample sizes. SEA is defined by an Eigen analysis of the covariance matrix involving the $\delta^{13}C$ and $\delta^{15}N$ values as x and y coordinates [$SEA = \pi ab$ (a and b representing the eigenvalues)]. Standard ellipses also embrace the covariance between isotopes, a feature that is not available in univariate representations. SEAc (standard ellipse areas corrected for sample size) were derived for the dietary sources (Fig. 2a) and the human samples from Early and Middle Mesolithic periods (Fig. 2c). For comparison, a plot of sources with associated standard deviations (Fig. 2b) was also supplied. SEAc was estimated using a maximum likelihood algorithm implemented in the package SIAR (Parnell et al., 2010) using R (version 3.3.1.).

Diet in generalist feeders such as humans includes many different sources, both animals and plants. The traditional way to proceed with isotopic reconstructions of prehistoric dietary protein is to plot human isotopic data in a bivariate space along with possible dietary sources, taking account of the fractionation between the dietary source and the consumer. Close vicinity within this bivariate space, often judged by eye, separates more important dietary sources from more peripheral sources. However, this approach does not account for the fact that all potential sources are not equally likely to be used, because of relative species abundance in the pertinent ecosystem as well as human foraging behaviour with respect to that ecosystem. The latter may be estimated with reference to the zooarchaeological record, albeit circumscribed by taphonomic processes. Nevertheless, balancing sources with reference to their frequency in the zooarchaeological record does provide a more realistic reconstruction of diet compared with a general, uniform model where each source is equally likely.

Bayesian mixture models provide a tool that can help disentangle multiple dietary sources and include both traditional uninformed, i.e. uniform models, and models weighted with prior information, i.e. informed models (here zooarchaeological frequencies inserted into an ethnographic framework). An uninformed prior implies that all dietary sources are equally likely to contribute to the human diet, whereas an informed prior assumes that all sources cannot be equally likely, and assesses the different sources according to the associated information.

Parnell et al. (2010) have developed an algorithm to estimate the proportions of different sources in a consumer's diet based on Bayesian analysis involving priors. Means, variances and error terms are accepted as inputs. Based on a linear model, Bayesian mixing estimates the proportion of sources using a Markov Chain Monte Carlo algorithm, given the constraint that the proportion of sources sums to unity. Bayesian models deliver probability distributions or point estimates of central tendencies with respect to the sources. The results here are presented as separate, uniform, environmental context-dependent chronological period boxplots, and as informed archaeological site-specific boxplots. The dietary contribution from the three main dietary categories (mammal, fish and plants) was summarized as pie charts for each context. The pie charts were constructed from the average value from each of the source categories modelled output mean. All mixing model computations were performed in R (version 3.3.1), using the application SIAR (Parnell et al., 2010). SIAR has been used previously in archaeological studies, e.g. Arcini et al. (2014), Bocherens et al. (2015) and de Armas et al. (2015).

The informed prior was derived as follows. Relevant sources were identified based on the zooarchaeological assemblage. Several methods can be used to quantify a zooarchaeological assemblage, from tallies such as number of identified specimens (NISP), the derivation minimal number of individuals (MNI), to more derived measures, such as analysis of bone counts by maximum likelihood (abcml) (Rogers, 2000) or most likely number of individuals (MLNI) (Konigsberg and Adams, 2014). Quantitative descriptions of bone assemblages involve a compromise between interdependence (where fragmentation could exaggerate NISP if all fragments have an equal probability of surviving) and aggregation (where MNI estimates are dependent on how archaeological contexts are defined). We assumed interdependence was not a major concern here and, because NISP is to be regarded as a fundamental measure while most other quantification units are derived (and often linked to NISP) (Lyman, 2008:79), using NISP facilitates replication and comparison with other studies. As Lyman (2008:81) concluded: ‘NISP is to be preferred over MNI as the quantitative unit used to measure taxonomic abundancies’.

Site-specific NISP data formed the basis for the informed priors after first being inserted into an ethnographic framework (Table 2), where hunting, gathering and fishing were set to 40%, 10% and 50%, respectively, corresponding to ethnographic data from latitudes matching southern Scandinavia (Marlowe, 2005). These general estimates were based on the percentage of food acquired by each foraging activity, and not the amount of protein gained from each food source. To rectify this bias, individual dietary sources were scaled based on the average protein proportions of the relevant species (Table 2, and see SD4). The protein scaling was based on information from the Swedish National Food Agency (Livsmedelsverket) and the National Nutrient Database from the United States Department of Agriculture (USDA). The informative prior was created by using the average amount of protein, rather than the amount of total energy per 100 g of tissue, from the species included in the different source categories (for exact protein values from the species included, see SD4). For example, in the pike category from Norje Sunnansund, the NISP was taken from the zooarchaeological assemblage and divided by the NISP for all fish in that assemblage (Scaled NISP, i.e. 1098/16,180). The Scaled NISP (0.068) was multiplied by 0.5, corresponding to the proportion of fish in the total diet, referred to as Total proportion (0.034). Note that the Total proportion values sum to 1 over all food sources. The amount of protein in a pike body was estimated to be 24.11% (g/kcal). The Total proportion (0.034) was then multiplied by the amount of protein (24.11%). The product was then normalized over all sources, so that the informative priors (0.050 for pike) summed to unity. Thus, the informative prior used was based on NISP and scaled according to the amount of protein in the relevant species.

3. Results

Stable isotopes of carbon and nitrogen measured in bulk collagen were used to assess dietary protein in prehistoric human remains (see the Methods). In order to interpret the individual protein sources in relation to the observed δ^{13}C and δ^{15}N values in the collagen from Early and Middle Mesolithic Scandinavian foragers, a bivariate plot is presented in Fig. 2ab; the trophic fractionation factors have been added to a baseline constructed from protein sources (Table 1; see SD1–3). The SEAc for Early Mesolithic ($n = 36$) and Middle Mesolithic ($n = 46$) samples were 10.028 and 7.835, respectively, demonstrating a narrowing of the isotopic niche width; their location in the bivariate area indicates an increasingly marine diet as the Mesolithic progresses (Fig. 2c), which was probably related to increasing salinity in the Baltic Sea.

The Early Mesolithic freshwater foragers displayed larger isotopic diversity and lower δ^{15}N values compared with Middle Mesolithic freshwater foragers (Fig. 2). This was not caused by a temporal trend within the Early Mesolithic period, i.e. the humans with the lowest δ^{15}N values were not generally among the oldest from within the Early Mesolithic period (see SD1). This suggests a larger dietary variation in the Early Mesolithic period, with higher levels of lower trophic-level food sources, i.e. terrestrial mammals and cyprinids in Early Mesolithic freshwater contexts. This was followed by a temporal increase in the Middle Mesolithic period associated with higher trophic-level food sources, i.e. non-cyprinid fish causing a temporal enrichment in ^{15}N, in association with the increasing salinity of the Baltic Sea, which caused a temporal enrichment in ^{13}C. The differences between the two periods were statistically significant, as illustrated by a standard two-sample *t*-test (Table 3).

The sample of Early Mesolithic marine foragers was small and limited to the Swedish west coast. The isotope signals were clustered, showing elevated δ^{13}C and δ^{15}N values, indicating a large input from marine sources. None of the Early Mesolithic foragers from the two biotopes displayed overlapping isotope signals, indicating limited mobility between coast and inland. The Middle Mesolithic marine foragers had more diverse isotope signals. Two of the individuals from a marine environmental context displayed freshwater environmental context isotope values, but the general trend indicated little overlap between foragers living in the two biotopes, suggesting limited, albeit present, coast to inland mobility

Table 2
The basis of the informative priors used in the Bayesian mixing model analysis. NISP, number of identified specimens; NA, not applicable.

Ethnographic estimation			Source name	Source code	NISP	Scaled NISP	Total proportion	Protein proportion	Prior
Norje Sunnansund		Fishing 50%	Pike	PIK	1098	0.068	0.034	24.11%	0.050
			Freshwater Mid-trophic Fish	FMF	2957	0.183	0.091	23.14%	0.130
			Cyprinid	CYP	11978	0.740	0.370	15.13%	0.344
			Freshwater Cata-/Anadromous fish	FCA	147	0.009	0.005	4.14%	0.001
		Hunting 40%	Terrestrial Herbivore	THE	744	0.534	0.214	19.64%	0.258
			Terrestrial Omnivore	TOM	357	0.256	0.103	15.06%	0.095
			Fresh Aquatic Mammal	FAM	291	0.209	0.084	20.00%	0.103
		Gathering 10%	Berries	BER	NA		0.025	1.27%	0.002
			Fruits	FRU			0.025	1.95%	0.003
			Hazelnuts	HAZ			0.025	1.98%	0.003
			Mushrooms	MUS			0.025	7.97%	0.012
Huseby klev	PBO-EBO	Fishing 50%	Marine High-trophic Fish	MHF	249	0.929	0.465	22.57%	0.559
			Marine Low-trophic Fish	MLF	19	0.071	0.035	12.59%	0.024
			Marine Cata-/Anadromous fish	MCA	0	0.000	0.000	9.05%	0.000
		Hunting 40%	Terrestrial Herbivore	THE	51	0.149	0.060	19.64%	0.062
			Terrestrial Omnivore	TOM	85	0.249	0.099	15.06%	0.080
			Marine Aquatic Mammal	MAM	206	0.602	0.241	20.00%	0.257
		Gathering 10%	Berries	BER	NA		0.025	1.27%	0.002
			Fruits	FRU			0.025	1.95%	0.003
			Hazelnuts	HAZ			0.025	1.98%	0.003
			Mushrooms	MUS			0.025	7.97%	0.011
	MBO	Fishing 50%	Marine High-trophic Fish	MHF	367	0.642	0.321	22.57%	0.426
			Marine Low-trophic Fish	MLF	205	0.358	0.179	12.59%	0.133
			Marine Cata-/Anadromous fish	MCA	0	0	0	9.05%	0.000
		Hunting 40%	Terrestrial Herbivore	THE	60	0.566	0.226	19.64%	0.262
			Terrestrial Omnivore	TOM	41	0.387	0.155	15.06%	0.137
			Marine Aquatic Mammal	MAM	5	0.047	0.019	20.00%	0.022
		Gathering 10%	Berries	BER	NA		0.025	1.27%	0.002
			Fruits	FRU			0.025	1.95%	0.003
			Hazelnuts	HAZ			0.025	1.98%	0.003
			Mushrooms	MUS			0.025	7.97%	0.012
Gisslause (Gotland)		Fishing 50%	Pike	PIK	67	0.158	0.079	24.11%	0.102
			Freshwater Mid-trophic Fish	FMF	220	0.520	0.260	23.14%	0.323
			Cyprinid	CYP	132	0.312	0.156	15.13%	0.127
			Freshwater Cata-/Anadromous fish	FCA	4	0.009	0.005	4.14%	0.001
		Hunting 40%	Terrestrial Herbivore	THE	33	0.040	0.016	19.64%	0.017
			Terrestrial Omnivore	TOM	0	0.000	0.000	15.06%	0.000
			Fresh Aquatic Mammal	FAM	788	0.960	0.384	20.00%	0.412
		Gathering 10%	Berries	BER	NA		0.025	1.27%	0.002
			Fruits	FRU			0.025	1.95%	0.003
			Hazelnuts	HAZ			0.025	1.98%	0.003
			Mushrooms	MUS			0.025	7.97%	0.011

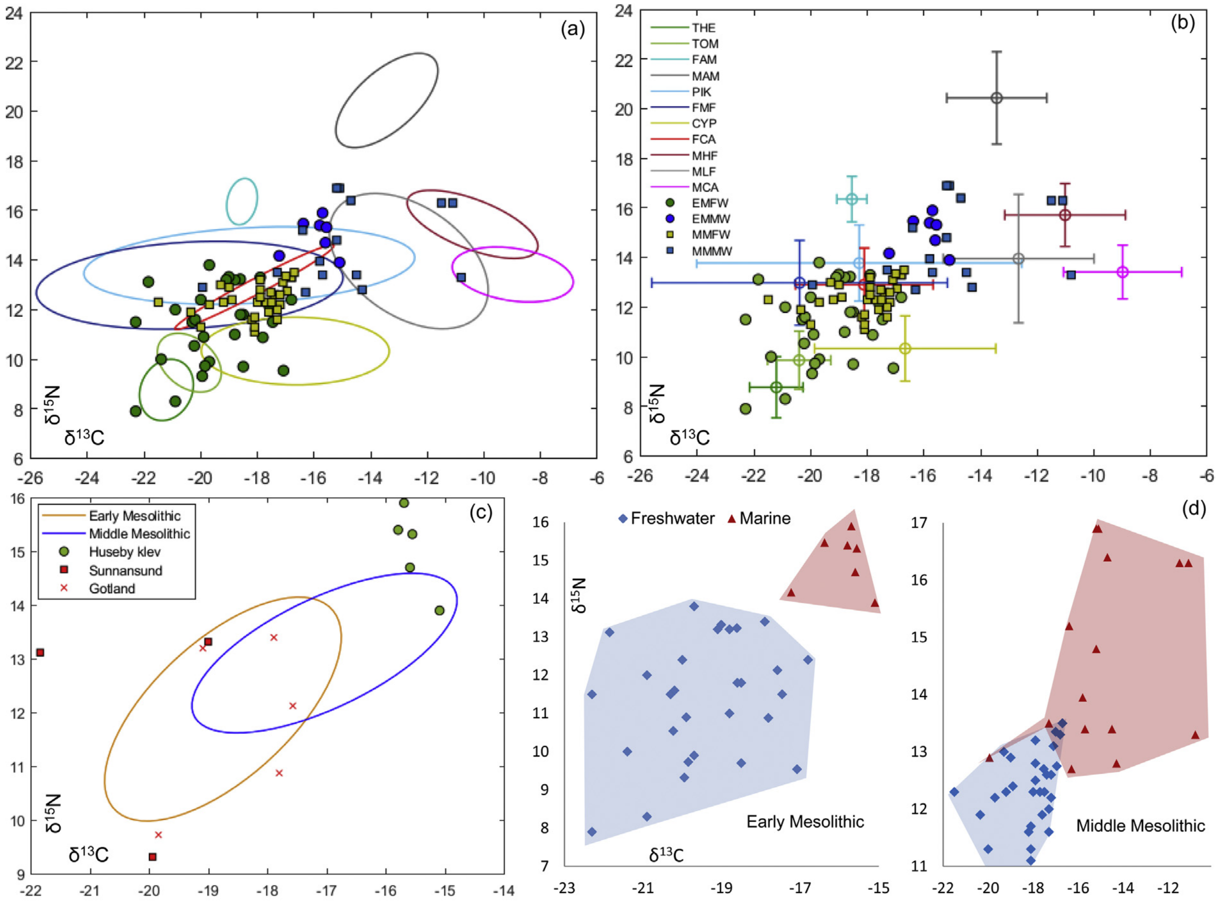

Fig. 2. (a,b) Bivariate graphs of all known Scandinavian Early and Middle Mesolithic foragers and the baseline for each source group [with 5‰ $^{13}C_{plants-human}$, 1‰ $^{13}C_{animal-collagen-human-collagen}$ and 4.7‰ $^{15}N_{all-sources-human}$ fractionation steps added (plants and mushrooms not shown)]; (a) using SEAc, (b) using mean values with one standard deviation. (c) Isotopic niche width for Early and Middle Mesolithic foragers, with human isotope values included from three different Early Mesolithic contexts, subjected to informed Bayesian analysis. (d) The human stable isotope values divided into freshwater and marine environmental contexts and Early and Middle Mesolithic periods. Source codes in Table 1. EMFW = Early Mesolithic freshwater; EMMW = Early Mesolithic marine water; MMFW = Middle Mesolithic freshwater; MMMW = Middle Mesolithic marine water.

Table 3
Descriptive statistics and results from a two-sample *t*-test, Early Mesolithic vs. Middle Mesolithic with unequal variance, two-sided.

Isotope	Sample	N	Mean	Standard deviation
$\delta^{13}C$	Early Mesolithic	36	−18.76	1.9716
	Middle Mesolithic	46	−17.04	2.2162
	t-test	$t = 3.650$, df = 80, $p = 0.0005$		
$\delta^{15}N$	Early Mesolithic	36	12.07	2.0519
	Middle Mesolithic	46	13.11	1.4672
	t-test	$t = 2.677$, df = 80, $p = 0.0090$		

during the Middle Mesolithic (Fig. 2d).

Although some of the categories only comprised a few specimens, so further interpretation has to be made with caution, some generalizations can be made. There does seem to be a general constriction of the isotopic niche width for humans in the Middle Mesolithic compared with the Early Mesolithic, and a shift from larger terrestrial mammals present in the earlier period to a stronger dependence on fish and marine sources during the Middle Mesolithic.

This trend is visible in the bivariate plot (Fig. 2). However, humans are omnivores and can consume a variety of different food sources, therefore a mixing model has the potential to be more informative than a bivariate graph. Furthermore, a regional approach lacks precision and cannot incorporate the local variations that could be anticipated given the geographical variation. A regional mixing approach assumes an 'average' diet (even when none exists) and initially considers each dietary source as equally important (even when they cannot be). Thus, a uniform regional mixing analysis does not result in a plausible model of diet, but rather a dietary trend arising from the generated 'average' values, which becomes important when trying to estimate the relative dietary proportions of fish, hunted mammals and gathered plants (Fig. 3).

However, there is more information available in the archaeological record than is used in a bivariate or uniform mixing approach, namely the zooarchaeological data. Although difficult to compare, because of problems related to the preservation and recovery of fish bones and plant material, the proportions of different species in the refuse layers at settlement sites can provide an indication of which species are more relevant than others. An informed Bayesian mixing model was used to expose the protein diet of individuals from four Early Mesolithic settlements: Huseby klev (two different settlement phases), Norje Sunnansund and Gisslause (Gotland) (Boethius, 2017, 2018a; Boethius et al., 2017). A proportional estimated protein input was provided for 9–11 different dietary sources, depending on the environmental context (see the Methods).

The individual human isotope values from the two Early Mesolithic freshwater sites were roughly homogeneous, although

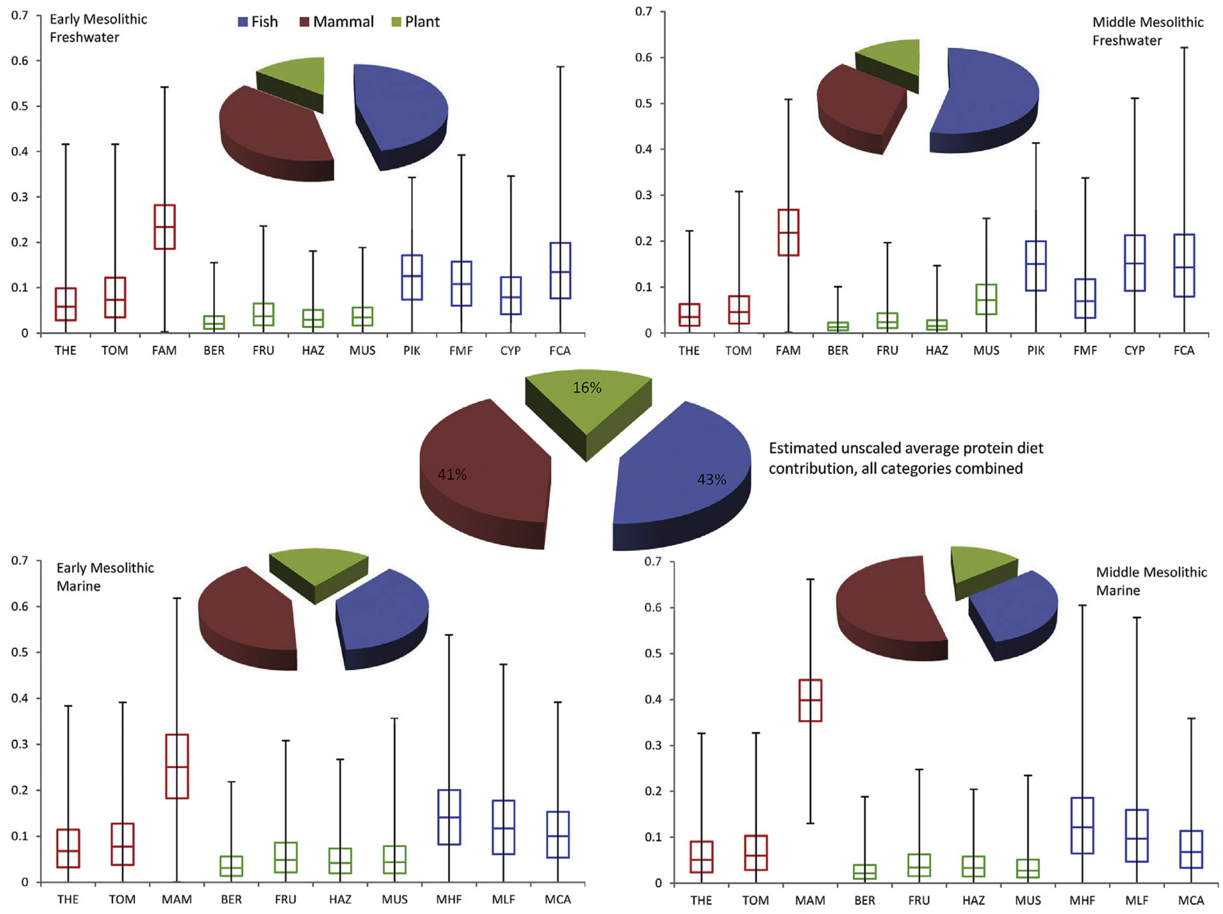

Fig. 3. Uniform Bayesian mixing models using the baselines of selected dietary sources (Table 1). Human isotope signals based on all currently available data. $N = 81$: Early Mesolithic freshwater, $n = 28$; Middle Mesolithic freshwater, $n = 31$; Early Mesolithic marine, $n = 7$; Middle Mesolithic, marine $n = 15$.

the values from Norje Sunnansund showed a somewhat larger isotopic diversity and the values from Gotland slightly higher δ^{13}C values (Fig. 2c). However, the informative dietary models based on these values showed that the diet in Norje Sunnansund differed from that of Gotland. While the human diets from both settlements were dominated by freshwater fish protein, the importance of individual fish species varied and seals constituted a significantly larger protein contribution on Gotland than at Norje Sunnansund (Fig. 4a and b).

Early Mesolithic marine settlements were represented by two separate phases from Huseby klev. In the bivariate analysis, the Huseby klev human isotope signals were clustered (Fig. 2c). However, when analysed in a mixing model, differences became apparent. Marine high-trophic fish were an important food source during both phases. The importance of marine mammals was apparent in the initial phase, but this was replaced by terrestrial mammals and lower trophic fish in the second phase of the site occupation. This suggests a diet dominated by aquatic resources with heterogeneous settlement-specific subsistence strategies (Fig. 4c and d).

4. Discussion

By using Bayesian mixing models it is possible to disentangle multiple dietary sources and illustrate source-specific dietary estimations. Modelling diet represents a balance between including too few sources or too many (cf. Fry, 2006). Too few may result in outcomes that are too coarse to be meaningful, while too many sources can result in overdetermination. The latter may result in flat posteriors, which were not encountered in this study.

The use of uniform analyses proved less valuable than informed analyses in this study. This was partly because of the large baseline range provided: dietary sources from all over southern Scandinavia were used to create the source baselines. The main problem with using a mixing model in this way is the assumption of environmental context-specific average diets. As shown in the informed analysis (Fig. 4), there were major, source-specific, differences in the diet between the foragers from the four settlements analysed. An average environmental context-source specific dietary estimation, as shown in Fig. 3, encompasses too much variation for optimal results; in contrast, an informed analysis can provide more information.

The results of the mixing models for the Early Mesolithic sites suggest a dominance of aquatic resources in both environmental contexts, i.e. fish. There is a general temporal elevation of human δ^{13}C and δ^{15}N isotope values from the Early Mesolithic to the Middle Mesolithic (Fig. 2), indicating a higher dependency on higher trophic level food sources (again fish), associated with increasing levels of salinity in the Baltic Sea. As mentioned, these results are based on the protein contribution to the diet. However, while it has been established that a forager diet is extremely high in protein (Cordain et al., 2000), humans cannot sustain a diet where more than 40% of the energy intake derives from protein (Cordain et al., 2000); fat and carbohydrates combined constitute at least 60% of a human diet. Fish and mammals are roughly similar in protein content, with variations dependent on their percentage of

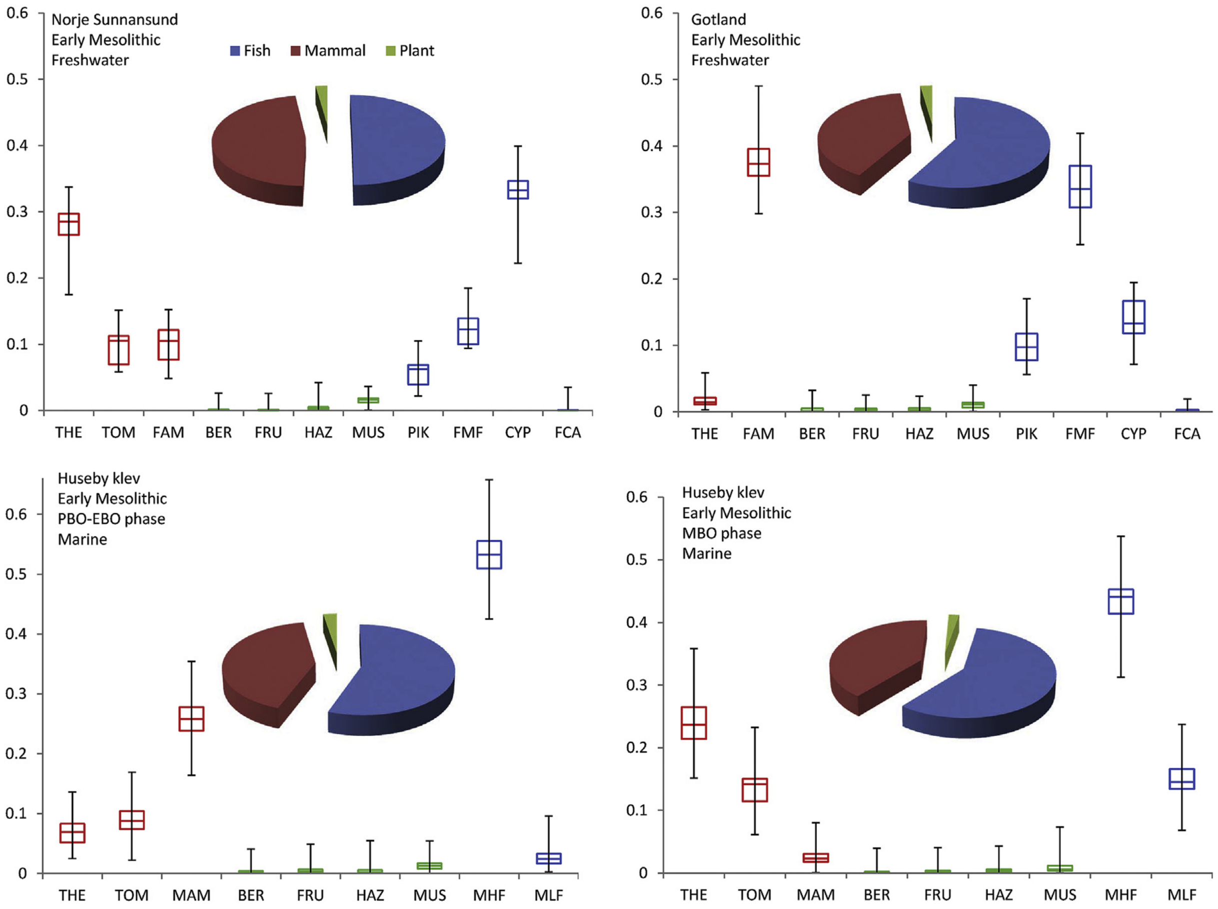

Fig. 4. Early Mesolithic settlement-specific informed Bayesian mixing models using the baselines of selected dietary sources (Table 1) and priors (Table 2). Human isotope signals based on all currently available data. *N* = 13: Norje Sunnansund dated to 9600–8600 cal. BP, *n* = 3; Gotland around 9200–8200 cal. BP, *n* = 5; Huseby klev PBO-EBO phase dated to 10,300–9600 cal. BP, *n* = 4; Huseby klev MBO phase dated to 9600–8700 cal. BP, *n* = 1.

body fat (Cordain et al., 2000), e.g. lean fish such as pike, perch, cod and ling are somewhat higher in relative protein content than red deer, seal or wild boar, while fatty fish such as eel and mackerel are lower in protein content (see SD4). Plants have relatively six times less protein content, on average, compared with fish and mammals, so the contribution of plants to the overall diet of humans is significantly larger than it appears (Fig. 4). When the protein contribution is modelled, mammal and fish tissues impact collagen more than plant tissues and thus contribute proportionally more to the protein proportion of the diet than to the overall energy intake.

An increasing dietary importance of fish in societies that are already strongly fish dependent, and a general decrease in isotopic niche width, imply a homogenization of subsistence strategies. However, a temporal enrichment in human δ^{15}N values was only observed in association with freshwater environmental contexts. From the marine environmental contexts, the human δ^{15}N values decreased slightly, with an average of 0.4 from Early to Middle Mesolithic. This means that either the transition towards a higher aquatic dependency began somewhat earlier in marine environmental contexts or, as can be seen from the temporal trend in Fig. 4c and d, people were consuming larger amounts of marine mammals in the earlier periods. This latter explanation is further supported by a general lack of marine mammal bones in both late Early and Late Mesolithic contexts, with a corresponding temporal increase in fish bone abundance, as at Huseby klev, and a shift in west coast settlement locations, which during the Pre-Boreal chronozone were located in areas where marine mammals could be optimally exploited, to, in later periods, locations more suited for fishing (Boethius, 2018a; Kindgren, 1996).

By highlighting the large spectra of dietary source combinations that can contribute to the δ^{13}C and δ^{13}N values in human collagen, this study shows the importance of applying protein estimates scaled by zooarchaeological remains in the interpretation of stable isotope signals. Human stable isotope values can be derived from a large range and combinations of dietary sources. Without any insight regarding how to interpret the stable isotope values, this dietary source variation can lead to misinterpretations of the results, reducing the usefulness of stable isotope data for all but extreme cases, e.g. for a diet based almost exclusively on aquatic top predators. The fusion of stable isotope analysis and zooarchaeology is advocated because it enables in-depth palaeodietary interpretations and protein dietary estimations for most aspects of a range of human diet scenarios.

5. Conclusions

The Early Holocene forager societies of Scandinavia faced a rejuvenated landscape, with an increasing biomass and new biotopes following the migration of fauna and flora to northern Europe as temperatures rose and glaciers vanished (Miller et al., 2008). The subsistence of Early (11,500–8500 cal. BP) and Middle (8500–7500 cal. BP) Mesolithic foragers is a pertinent research field, especially given the substantial shifts in climate and the reshaping of the landscape as a result of sea-level change. The findings presented here call for a revised view of the lifeways of Early and Middle Mesolithic foragers in southern Scandinavia. The results demonstrate that fish, both marine and freshwater species, played a significant role in the diet of Mesolithic foragers. Previous research has downplayed the importance of fish and emphasized the hunting of mammals (Jochim, 2011): ungulates at inland locations (Blankholm, 1996) and seals in coastal areas (Bjerck, 2009). While seals appeared to have been important for subsistence in some areas, in general terrestrial mammals appeared less important. The key result of this study is the demonstration that fish have been more important in the establishment of human populations in northern Europe than previously realized. That the importance of fish is only now being recognized is partly because earlier field excavation techniques did not facilitate the recovery of minute fish bones, and previous human isotope studies neither coped with the broad isotopic baselines of various fish nor recognized fully the foraging diet as a mixture of different subsistence sources. The zooarchaeological analyses of three Early Mesolithic sites indicate that traditional interpretations are not in accordance with new empirical findings (Boethius, 2016b, 2017, 2018a; Boethius et al., 2017). The results arising from the compilation of previously published human isotope data and a new, large, isotope data set, in combination with revisions of trophic fractionation factors and advances in Bayesian mixing analysis, necessitate a rethinking of Mesolithic subsistence.

Although this is a study of human diet, the results are important in a wider sense, as a diet based on aquatic, rather than terrestrial, resources may be connected with lower levels of residential mobility (Kelly, 2013:90; Marlowe, 2005:Fig. 6; Yesner, 1980), particularly if the capacity to store large quantities of food and the knowledge to use mass-harvesting technologies existed (Binford, 2001:398; Kelly, 2013:127). The capacity for large-scale food storage (fish fermentation) and mass-harvesting of fish has been identified in Early Mesolithic contexts from southern Scandinavia (Boethius, 2016b; Nilsson et al., 2018), suggesting that delayed-return subsistence strategies may have been possible (Boethius, 2017). A reliance on aquatic resources under these circumstances implies an ability to cope more easily with environmental, climatic and ecological changes without resorting to subsistence strategies based just on mobility. In freshwater contexts, this type of subsistence strategy could be achieved by access to productive freshwater systems, e.g. hypertrophicated lakes (Boethius et al., 2017; Boethius, 2018c), with connections to larger water bodies via rivers or springs, facilitating mass catching opportunities during different times of the year as different species aggregate for spawning activities (Bērziņš, 2010). In marine environments similar results could be achieved by making use of fish species that were present all year, as well as fish migrations and seasonal abundance (Enghoff, 2011; McMillan et al., 2008).

The low degree of overlap in isotopic values between humans in marine and freshwater environmental contexts suggests limited mobility between coast and inland, or at least not enough mobility to leave chemical traces in human bone collagen based on dietary input (Fig. 2d). Together with a temporal increase in fish dependency (suggested by a temporal increase in δ^{15}N values in freshwater contexts and a slight decrease in marine contexts) and a corresponding diminishing of isotopic niche width (Fig. 2c), this might indicate decreasing mobility caused by an increasing association with certain key areas in the landscape. However, decreasing mobility is only likely if other prerequisites are met, e.g. resources are sufficiently abundant, reliable and limited geographically, storage opportunities are available, and there is access to mass-harvesting technology (Ames, 1994; Matson, 1983; Testart, 1982). While intra-individual differences in δ^{13}C and δ^{15}N values between dentine and bone collagen have been interpreted as indicating a high level of mobility among Scandinavian Mesolithic foragers (Günther et al., 2018:S1), these differences could be the result of logistical and not residential mobility. Seasonal or task-specific forays, i.e. logistical mobility, impact stable isotope signals in dentine more than bone, because the development time for dentine is shorter (AlQahtani et al., 2010; Montgomery et al., 2013; Moorrees et al., 1963) than the time taken for bone remodelling (cf. Kini and Nandeesh, 2012; Sims and Martin, 2014). Consequently, if seasonal forays were made during both adolescence (when dentine is formed) and adulthood (when bones were remodelled), the more limited formation period would cause the diet during a seasonal absence, e.g. from a sedentary settlement, to make up a larger proportion of the stable isotope values, and 'external' dietary sources would influence the stable isotope signals in the collagen more in dentine compared with bone. Thus differences in stable isotope signals between dentine and bone offer less information regarding levels of residential mobility than the almost complete separation of forager stable isotope values based on environmental context seen here.

If the diminishing isotopic niche width is related to diet homogenization, it could imply a temporal trend of decreasing mobility during the Early to Middle Mesolithic period. These ideas can be related to those of Kelly, who argues that 'When one group becomes sedentary, for example, at the mouth of a productive salmon stream, they remove a resource patch from others. This makes the environment more patchy and increases the cost of moving. Once established, then, a single sedentary village encourages its neighbors to become sedentary … Therefore, we might expect sedentary communities to occur in batches rather that singly' (Kelly, 2013:107).

An increasing reliance on fish does not in itself represent a direct pathway to decreasing mobility (Bailey and Milner, 2002; Moss, 2012; Zangrando, 2009). However, a diminishing residential mobility can be suggested if a high dependency on aquatic resources (Fig. 4) can also be connected to limited coast to inland mobility (Fig. 2d), a diminishing isotopic niche width (Fig. 2c), mass catching technologies, e.g. contemporaneous fish traps and nets from various Mesolithic sites (Hadevik et al., 2008; Hansson et al., 2018; Miettinen et al., 2008; Mårtensson, 2001; Pedersen, 1995; Pälsi, 1920), the capacity to store large resource abundance, e.g. by fermentation (Boethius, 2016b) or drying (Woodman, 1985a, b) and year-round seasonality indicators and selective hunting strategies (Boethius, 2017). Consequently, it can be argued that by increasing the amount of fish in the diet, the Early and Middle Mesolithic southern Scandinavian foragers became more resilient to external perturbations and were able cope with their environment through many different subsistence strategies, of which mobility was perhaps no longer the first choice.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.jas.2018.02.018.

References

Aaris-Sørensen, K., Petersen, E.B., 1986. The Prejlerup aurochs-an archaeozoological discovery from Boreal Denmark. Congrès international d'archéozoologie 5, 99–109.

Aaris-Sørensen, K., 1976. A zoological investigation of the bone material from Sværdborg I–1943. In: Henriksen, B. (Ed.), Sværdborg I. Excavations 1943-44. A Settlement of the Maglemose Culture. Arkeologiske Studier, vol. 3. Akademisk Forlag, Copenhagen.

AlQahtani, S.J., Hector, M., Liversidge, H., 2010. Brief communication: the London atlas of human tooth development and eruption. Am. J. Phys. Anthropol. 142, 481–490.

Ambrose, S.H., 1990. Preparation and characterization of bone and tooth collagen for isotopic analysis. J. Archaeol. Sci. 17, 431–451.

Ambrose, S.H., 2000. Controlled diet and climate experiments on nitrogen isotope ratios of rats. In: Ambrose, S.H., Katzenberg, M.A. (Eds.), Biogeochemical Approaches to Paleodietary Analysis. Kluwer academic publishers, New York, pp. 243–259.

Ambrose, S.H., DeNiro, M.J., 1986. Reconstruction of African human diet using bone collagen carbon and nitrogen isotope ratios. Nature 319, 321–324.

Ames, K.M., 1994. The Northwest Coast: complex hunter-gatherers, ecology, and social evolution. Annu. Rev. Anthropol. 23, 209–229.

Andrén, T., Björck, S., Andrén, E., Conley, D., Zillén, L., Anjar, J., 2011. The development of the Baltic Sea Basin during the last 130 ka. In: J, H., S, B., P, H. (Eds.), The Baltic Sea Basin. Springer, Berlin, pp. 75–97.

Arcini, C., Ahlström, T., Tagesson, G., 2014. Variations in diet and stature: are they linked? Bioarchaeology and paleodietary Bayesian mixing models from Linköping, Sweden. Int. J. Osteoarchaeol. 24, 543–556.

Auerswald, K., Wittmer, M.H., Zazzo, A., Schäufele, R., Schnyder, H., 2010. Biases in the analysis of stable isotope discrimination in food webs. J. Appl. Ecol. 47, 936–941.

Bailey, G., Milner, N., 2002. Coastal hunter-gatherers and social evolution: marginal or central? Before Farming 2002, 1–22.

Bērziņš, V., 2010. Fishing seasonality and techniques in prehistory; why freshwater fish are special. Archaeologia Baltica 13, 37–42.

Binford, L.R., 2001. Constructing Frames of Reference: an Analytical Method for Archaeological Theory Building Using Ethnographic and Environmental Data Sets. University of California Press, Berkeley.

Bjerck, H.B., 2009. Colonizing seascapes: comparative perspectives on the development of maritime relations in Scandinavia and Patagonia. Arctic Anthropol. 46, 118–131.

Björck, S., 1995. A review of the history of the Baltic Sea, 13.0-8.0 ka BP. Quat. Int. 27, 19–40.

Blankholm, H.P., 1996. On the Track of a Prehistoric Economy: Maglemosian Subsistence in Early Postglacial South Scandinavia. Aarhus Universitetsforlag, Aarhus.

Bocherens, H., Drucker, D., 2003. Trophic level isotopic enrichment of carbon and nitrogen in bone collagen: case studies from recent and ancient terrestrial ecosystems. Int. J. Osteoarchaeol. 13, 46–53.

Bocherens, H., Drucker, D.G., Germonpré, M., Lázničková-Galetová, M., Naito, Y.I., Wissing, C., Brůžek, J., Oliva, M., 2015. Reconstruction of the Gravettian food-web at Předmostí I using multi-isotopic tracking (13 C, 15 N, 34 S) of bone collagen. Quat. Int. 359, 211–228.

Boethius, A., 2016a. Osteologiska analyser av det mesolitiska materialet. In: Kjällquist, M., Emilsson, A., Boëthius, A. (Eds.), Norje Sunnansund. Boplatslämningar Från Tidigmesolitikum Och Järnålder. Särskild arkeologisk undersökning 2011 och arkeologisk förundersökning 2011 och 2012, Ysane socken, Sölvesborgs kommun i Blekinge län. Karlskrona: Blekinge museum.

Boethius, A., 2016b. Something rotten in Scandinavia: the world's earliest evidence of fermentation. J. Archaeol. Sci. 66, 169–180.

Boethius, A., 2017. Signals of sedentism: faunal exploitation as evidence of a delayed-return economy at Norje Sunnansund, an Early Mesolithic site in south-eastern Sweden. Quat. Sci. Rev. 162, 145–168.

Boethius, A., 2018a. Huseby klev and the quest for pioneer subsistence strategies: diversification of a maritime lifestyle. In: Persson, P., Skar, B., Breivik, H.M., Riede, F., Jonsson, L. (Eds.), The Ecology of Early Settlement in Northern Europe - Conditions for Subsistence and Survival. Equinox, Sheffield, pp. 99–128.

Boethius, A., 2018b. The use of aquatic resources by Early Mesolithic foragers in southern Scandinavia. In: Persson, P., Skar, B., Breivik, H.M., Riede, F., Jonsson, L. (Eds.), The Ecology of Early Settlement in Northern Europe - Conditions for Subsistence and Survival. Equinox, Sheffield, pp. 311–334.

Boethius, A., 2018c. Fishing for Ways to Thrive: Integrating Zooarchaeology to Understand Subsistence Strategies and Their Implications Among Early and Middle Mesolithic Southern Scandinavian Foragers. Acta Archaeologica Lundensia Series in 8°, vol 70. Lund University, Lund. Studies in Osteology 4.

Boethius, A., Storå, J., Hongslo Vala, C., Apel, J., 2017. The importance of freshwater fish in Early Holocene subsistence: exemplified with the human colonization of the island of Gotland in the Baltic basin. J. Archaeol. Sci.: Report 13, 625–634.

Borrman, H., Engström, E., Alexandersen, V., Jonsson, L., Gerdin, A., Carlsson, G., 1995. Dental conditions and temporomandibular joints in an early mesolithic bog man. Swed. Dent. J. 20, 1–14.

Brodie, C.R., Leng, M.J., Casford, J.S., Kendrick, C.P., Lloyd, J.M., Yongqiang, Z., Bird, M.I., 2011. Evidence for bias in C and N concentrations and δ 13 C composition of terrestrial and aquatic organic materials due to pre-analysis acid preparation methods. Chem. Geol. 282, 67–83.

Brown, T.A., Nelson, D.E., Vogel, J.S., Southon, J.R., 1988. Improved collagen extraction by modified Longin method. Radiocarbon 30, 171–177.

Carter, R.J., 2001. Dental indicators of seasonal human presence at the Danish Boreal sites of Holmegaard I, IV and V and Mullerup and the Atlantic sites of Tybrind Vig and Ringkloster. Holocene 11, 359–365.

Caut, S., Angulo, E., Courchamp, F., 2008. Discrimination factors (Δ15N and Δ13C) in an omnivorous consumer: effect of diet isotopic ratio. Funct. Ecol. 22, 255–263.

Caut, S., Angulo, E., Courchamp, F., 2009. Variation in discrimination factors (Δ15N and Δ13C): the effect of diet isotopic values and applications for diet reconstruction. J. Appl. Ecol. 46, 443–453.

Codron, D., Sponheimer, M., Codron, J., Newton, I., Lanham, J.L., Clauss, M., 2012. The confounding effects of source isotopic heterogeneity on consumer–diet and tissue–tissue stable isotope relationships. Oecologia 169, 939–953.

Cohen, J.E., 1994. Marine and continental food webs: three paradoxes? Phil. Trans. Roy. Soc. Lond. B 343, 57–69.

Cordain, L., Miller, J.B., Eaton, S.B., Mann, N., Holt, S.H., Speth, J.D., 2000. Plant-animal subsistence ratios and macronutrient energy estimations in worldwide hunter-gatherer diets. Am. J. Clin. Nutr. 71, 682–692.

Dalerum, F., Angerbjörn, A., 2005. Resolving temporal variation in vertebrate diets using naturally occurring stable isotopes. Oecologia 144, 647–658.

de Armas, Y.C., Buhay, W.M., Suárez, R.R., Bestel, S., Smith, D., Mowat, S.D., Roksandic, M., 2015. Starch analysis and isotopic evidence of consumption of cultigens among Fisher–gatherers in Cuba: the archaeological site of Canímar Abajo, Matanzas. J. Archaeol. Sci. 58, 121–132.

DeNiro, M.J., 1985. Postmortem preservation and alteration of in vivo bone collagen isotope ratios in relation to palaeodietary reconstruction. Nature 317, 806–809.

DeNiro, M.J., Epstein, S., 1981. Influence of diet on the distribution of nitrogen isotopes in animals. Geochem. Cosmochim. Acta 45, 341–351.

Emeis, K.-C., Struck, U., Blanz, T., Kohly, A., Voβ, M., 2003. Salinity changes in the central Baltic Sea (NW Europe) over the last 10000 years. Holocene 13, 411–421.

Enghoff, I.B., 2007. Viking age fishing in Denmark, with particular focus on the freshwater site Viborg, methods of excavation and smelt fishing. In: Plogmann, H.H. (Ed.), International Council for Archaeozoology. Verlag Marie Leidorf, Rahden/Westf, pp. 69–76. Fish Remains Working Group. Meeting (2007). The role of fish in ancient time: proceedings of the 13th meeting of the ICAZ Fish Remains Working Group in October 4th - 9th, Basel/Augst 2005.

Enghoff, I.B., 2011. Regionality and Biotope Exploitation in Danish Ertebølle and Adjoining Periods. Scientia danica. Series B, Biologica, 1904-5484. Det Kongelige Danske Videnskabernes Selskab, Copenhagen.

Eriksson, G., 2003. Norm and Difference: Stone Age Dietary Practice in the Baltic Region. Jannes Snabbtryck Kuvertproffset HB, Stockholm.

Eriksson, G., Frei, K.M., Howcroft, R., Gummesson, S., Molin, F., Lidén, K., Frei, R., Hallgren, F., 2016. Diet and mobility among Mesolithic hunter-gatherers in Motala (Sweden)-The isotope perspective. J. Archaeol. Sci. Reports (in press) https://doi.org/10.1016/j.jasrep.2016.05.052.

Fernandes, R., Nadeau, M.-J., Grootes, P.M., 2012. Macronutrient-based model for dietary carbon routing in bone collagen and bioapatite. Archaeological and Anthropological Sciences 4, 291–301.

Fischer, A., Olsen, J., Richards, M., Heinemeier, J., Sveinbjörnsdóttir, Á.E., Bennike, P., 2007. Coast–inland mobility and diet in the Danish Mesolithic and Neolithic: evidence from stable isotope values of humans and dogs. J. Archaeol. Sci. 34, 2125–2150.

Florin, S.T., Felicetti, L.A., Robbins, C.T., 2011. The biological basis for understanding and predicting dietary-induced variation in nitrogen and sulphur isotope ratio discrimination. Funct. Ecol. 25, 519–526.

Fornander, E., 2011. A shattered tomb of scattered people: the Alvastra Dolmen in light of stable isotopes. Current Swedish Archaeology 19, 113–141.

Fry, B., 2006. Stable Isotope Ecology. Springer, New York.

Grey, J., Jones, R.I., Sleep, D., 2000. Stable isotope analysis of the origins of zooplankton carbon in lakes of differing trophic state. Oecologia 123, 232–240.

Günther, T., Malmström, H., Svensson, E.M., Omrak, A., Sánchez-Quinto, F., Kılınç, G.M., Krzewińska, M., Eriksson, G., Fraser, M., Edlund, H., Munters, A.R., Coutinho, A., Simões, L.G., Vicente, M., Sjölander, A., Jansen Sellevold, B., Jørgensen, R., Claes, P., Shriver, M.D., Valdiosera, C., Netea, M.G., Apel, J., Lidén, K., Skar, B., Storå, J., Götherström, A., Jakobsson, M., 2018. Population genomics of Mesolithic Scandinavia: investigating early postglacial migration routes and high-latitude adaptation. PLoS Biol. 16 e2003703.

Hadevik, C., Hammarstrand Dehman, K., Serlander, D., 2008. Arkeologiska Förundersökningar I Form Av Schaktningsövervakning 2003–2007 Malmö C Nedre – I Samband Med Byggandet Av Tunnel Och Ny Stationsbyggnad. Enheten för Arkeologi Rapport 2008:030. Malmö.

Hansson, A., Nilsson, B., Sjöström, A., Björck, S., Holmgren, S., Linderson, H., Magnell, O., Rundgren, M., Hammarlund, D., 2018. A submerged Mesolithic lagoonal landscape in the Baltic Sea, south-eastern Sweden – early Holocene environmental reconstruction and shore-level displacement based on a multiproxy approach. Quat. Int. 463, 110–123.

Hecky, R., Hesslein, R., 1995. Contributions of benthic algae to lake food webs as revealed by stable isotope analysis. J. North Am. Benthol. Soc. 14, 631–653.

Hedges, R.E., Reynard, L.M., 2007. Nitrogen isotopes and the trophic level of humans in archaeology. J. Archaeol. Sci. 34, 1240–1251.

Howland, M.R., Corr, L.T., Young, S.M., Jones, V., Jim, S., Van Der Merwe, N.J., Mitchell, A.D., Evershed, R.P., 2003. Expression of the dietary isotope signal in the compound-specific δ13C values of pig bone lipids and amino acids. Int. J. Osteoarchaeol. 13, 54–65.

Hultgreen, T., Johansen, O., Lie, R., 1985. Stiurhelleren i Rana Dokumentasjon av korn, husdyr og sild i yngre steinalder. Viking 48, 83–102.

Hussey, N.E., MacNeil, M.A., McMeans, B.C., Olin, J.A., Dudley, S.F., Cliff, G., Wintner, S.P., Fennessy, S.T., Fisk, A.T., 2014. Rescaling the trophic structure of marine food webs. Ecol. Lett. 17, 239–250.

Indermühle, A., Stocker, T., Joos, F., Fischer, H., Smith, H., Wahlen, M., Deck, B., Mastroianni, D., Tschumi, J., Blunier, T., 1999. Holocene carbon-cycle dynamics based on CO2 trapped in ice at Taylor Dome, Antarctica. Nature 398, 121–126.

Jackson, A.L., Inger, R., Parnell, A.C., Bearhop, S., 2011. Comparing isotopic niche widths among and within communities: SIBER–Stable Isotope Bayesian Ellipses in R. J. Anim. Ecol. 80, 595–602.

Jenkins, S.G., Partridge, S.T., Stephenson, T.R., Farley, S.D., Robbins, C.T., 2001. Nitrogen and carbon isotope fractionation between mothers, neonates, and nursing offspring. Oecologia 129, 336–341.

Jochim, M.A., 2011. The mesolithic. In: Milisauskas, S. (Ed.), European Prehistory. Springer, New York, pp. 115–142.

Jørkov, M.L.S., Heinemeier, J., Lynnerup, N., 2007. Evaluating bone collagen extraction methods for stable isotope analysis in dietary studies. J. Archaeol. Sci. 34, 1824–1829.

Katzenberg, M.A., 1989. Stable isotope analysis of archaeological faunal remains from southern Ontario. J. Archaeol. Sci. 16, 319–329.

Katzenberg, M.A., Goriunova, O., Weber, A., 2009. Paleodiet reconstruction of Bronze age Siberians from the mortuary site of Khuzhir-Nuge XIV, Lake Baikal. J. Archaeol. Sci. 36, 663–674.

Katzenberg, M.A., Weber, A., 1999. Stable isotope ecology and palaeodiet in the Lake Baikal region of Siberia. J. Archaeol. Sci. 26, 651–659.

Kelly, R.L., 2013. The Lifeways of Hunter-gatherers: the Foraging Spectrum. Cambridge University Press, , Cambridge.

Kindgren, H., 1996. Reindeer or seals? Some Late palaeolithic sites in central Bohuslän. Acta archaeologica Lundensia 191–205. Series in 8.

Kini, U., Nandeesh, B., 2012. Physiology of bone formation, remodeling, and metabolism. In: Fogelman, I., Gnanasegaran, G., van der Wall, H. (Eds.), Radionuclide and Hybrid Bone Imaging. Springer, Berlin, pp. 29–57.

Konigsberg, L.W., Adams, B., 2014. Estimating the number of individuals represented by commingled human remains: a critical evaluation of methods. In: Adams, B., Byrd, J. (Eds.), Commingled Human Remains: Methods in Recovery, Analysis, and Identification. Academic Press, Amsterdam, pp. 193–220.

Larsson, L., 1982. Segebro: en tidigatlantisk boplats vid Sege ås mynning. Malmö museum, Malmö.

Leduc, C., 2012. Ungulates exploitation for subsistence and raw material, during the Maglemose culture in Denmark: the example of Mullerup site (Sarauw's Island) in Sjælland. Danish Journal of Archaeology 1, 62–81.

Lee-Thorp, J.A., Sealy, J.C., Van der Merwe, N.J., 1989. Stable carbon isotope ratio differences between bone collagen and bone apatite, and their relationship to diet. J. Archaeol. Sci. 16, 585–599.

Lidén, K., 1996. A dietary perspective on Swedish hunter-gatherer and Neolithic populations. Laborativ Arkeologi 9, 5–23.

Livsmedelsverket. Livsmedelsverkets livsmedelsdatabas version, se sökfunktionen [Online]. Uppsala. Available: http://www7.slv.se/SokNaringsinnehall [Accessed September 2017].

Longin, R., 1971. New method of collagen extraction for radiocarbon dating. Nature 230, 241–242.

Longinelli, A., Langone, L., Ori, C., Giglio, F., Selmo, E., Sgavetti, M., 2013. Atmospheric CO 2 concentrations and δ 13 C values during 2011–2012 voyage: Mediterranean, Atlantic Ocean, southern indian Ocean and New Zealand to Antarctica. Atmos. Environ. 77, 919–926.

Lyman, R.L., 2008. Quantitative Paleozoology. Cambridge University Press, Cambridge.

Malainey, M.E., 2011. A Consumer's Guide to Archaeological Science: Analytical Techniques, Manuals in Archaeological Method, Theory and Technique. Springer, New York.

Marlowe, F.W., 2005. Hunter-gatherers and human evolution. Evol. Anthropol. 14, 54–67.

Matson, R.G., 1983. Intensification and the development of cultural complexity: the Northwest versus the Northeast coast. In: Nash, R.J. (Ed.), The Evolution of Maritime Cultures on the Northeast and Northwest Coasts of America. Department of Archaeology, Simon Fraser University, Burnaby, pp. 125–148.

McCutchan, J.H., Lewis, W.M., Kendall, C., McGrath, C.C., 2003. Variation in trophic shift for stable isotope ratios of carbon, nitrogen, and sulfur. Oikos 102, 378–390.

McMillan, A.D., McKechnie, I., St Claire, D.E., Frederick, S.G., 2008. Exploring variability in maritime resource use on the Northwest Coast: a case study from Barkley Sound, western Vancouver Island. Canadian Journal of Archaeology/Journal Canadien d'Archéologie 214–238.

Miettinen, A., Sarmaja-Korjonen, K., Sonninen, E., Jungner, H., Lempiäinen, T., Ylikoski, K., Mäkiaho, J., Carpelan, C., 2008. The palaeoenvironment of the'Antrea net find'. Iskos 16, 71–87.

Miller, P.A., Giesecke, T., Hickler, T., Bradshaw, R.H., Smith, B., Seppä, H., Valdes, P.J., Sykes, M.T., 2008. Exploring climatic and biotic controls on Holocene vegetation change in Fennoscandia. J. Ecol. 96, 247–259.

Milner, N., Craig, O.E., Bailey, G.N., Pedersen, K., Andersen, S.H., 2004. Something fishy in the Neolithic? A re-evaluation of stable isotope analysis of Mesolithic and Neolithic coastal populations. Antiquity 78, 9–22.

Minagawa, M., Wada, E., 1984. Stepwise enrichment of 15N along food chains: further evidence and the relation between δ15N and animal age. Geochem. Cosmochim. Acta 48, 1135–1140.

Montgomery, J., Beaumont, J., Jay, M., Keefe, K., Gledhill, A.R., Cook, G.T., Dockrill, S.J., Melton, N.D., 2013. Strategic and sporadic marine consumption at the onset of the Neolithic: increasing temporal resolution in the isotope evidence. Antiquity 87, 1060–1072.

Moorrees, C.F., Fanning, E.A., Hunt Jr., E.E., 1963. Age variation of formation stages for ten permanent teeth. J. Dent. Res. 42, 1490–1502.

Moss, M.L., 1961. Osteogenesis of acellular teleost fish bone. Am. J. Anat. 108, 99–109.

Moss, M.L., 2012. Understanding variability in Northwest Coast faunal assemblages: beyond economic intensification and cultural complexity. J. I. Coast Archaeol. 7, 1–22.

Mårtensson, J., 2001. Mesolitiskt trä. In: Karsten, P., Knarrström, B. (Eds.), Tågerup Specialstudier. UV Syd, Avd. för arkeologiska undersökningar, Lund, pp. 280–301.

Newsome, S.D., Martinez del Rio, C., Bearhop, S., Phillips, D.L., 2007. A niche for isotopic ecology. Front. Ecol. Environ. 5, 429–436.

Nilsson, B., Sjöström, A., Persson, P., 2018. Seascapes of Stability and change: the archaeological and ecological potential of early mesolithic seascapes, with examples from Haväng in the south-Eastern Baltic, Sweden. In: Persson, P., Skar, B., Breivik, H.M., Riede, F., Jonsson, L. (Eds.), The Ecology of Early Settlement in Northern Europe - Conditions for Subsistence and Survival. Equinox, Sheffield.

O'Connell, T., Kneale, C., Tasevska, N., Kuhnle, G., 2012. The diet-body offset in human nitrogen isotopic values: a controlled dietary study. Am. J. Phys. Anthropol. 149, 426–434.

Parnell, A.C., Inger, R., Bearhop, S., Jackson, A.L., 2010. Source partitioning using stable isotopes: coping with too much variation. PLoS One 5 (3) e9672.

Pawełczyk, S., Pazdur, A., 2004. Carbon isotopic composition of tree rings as a tool for biomonitoring CO2 level. Radiocarbon 46, 701–719.

Payne, S., 1972. Partial recovery and sample bias: the results of some sieving experiments. In: Higgs, E. (Ed.), Papers in Economic Prehistory. Cambridge University Press, Cambridge, pp. 49–64.

Pedersen, L., 1995. 7000 years of fishing: stationary fishing structures in the Mesolithic and afterwards. In: Fischer, A. (Ed.), Man and Sea in the Mesolithic : Coastal Settlement above and below Present Sea Level : Proceedings of the International Symposium, Kalundborg, Denmark 1993. Oxbow monograph, Oxford, pp. 75–86.

Perga, M.E., Grey, J., 2010. Laboratory measures of isotope discrimination factors: comments on Caut, Angulo & Courchamp (2008, 2009). J. Appl. Ecol. 47, 942–947.

Phillips, D.L., Inger, R., Bearhop, S., Jackson, A.L., Moore, J.W., Parnell, A.C., Semmens, B.X., Ward, E.J., 2014. Best practices for use of stable isotope mixing models in food-web studies. Can. J. Zool. 92, 823–835.

Post, D.M., 2002. Using stable isotopes to estimate trophic position: models, methods, and assumptions. Ecology 83, 703–718.

Påsse, T., Andersson, L., 2005. Shore-level displacement in Fennoscandia calculated from empirical data. GFF 127, 253–268.

Pälsi, S., 1920. Ein steinzeitlicher Moorfund bei Korpilahti im Kirchspiel Antrea, Län Viborg (XXVIII). Suomen muinaismuistoyhdistyksen aikakauskirja 2, 3–22.

Ramsey, C.B., Higham, T., Bowles, A., Hedges, R., 2004. Improvements to the pretreatment of bone at Oxford. Radiocarbon 46, 155–164.

Richards, M.P., Hedges, R.E., 1999. Stable isotope evidence for similarities in the types of marine foods used by Late Mesolithic humans at sites along the Atlantic coast of Europe. J. Archaeol. Sci. 26, 717–722.

Riede, F., 2014. The resettlement of northern Europe. In: Cummings, V., Jordan, P., Zvelebil, M. (Eds.), The Oxford Handbook of the Archaeology and Anthropology of Hunter-Gatherers. Oxford University Press, Oxford, pp. 556–581.

Robson, H., Andersen, S., Craig, O., Fischer, A., Glykou, A., Hartz, S., Lübke, H., Schmölcke, U., Heron, C., 2012. Carbon and nitrogen isotope signals in eel bone collagen from Mesolithic and Neolithic sites in northern Europe. J. Archaeol. Sci. 39, 2003–2011.

Robson, H.K., Andersen, S.H., Clarke, L., Craig, O.E., Gron, K.J., Jones, A.K., Karsten, P., Milner, N., Price, T.D., Ritchie, K., 2016. Carbon and nitrogen stable isotope values in freshwater, brackish and marine fish bone collagen from Mesolithic and Neolithic sites in central and northern Europe. Environ. Archaeol. 21, 105–118.

Rogers, Alan R., 2000. Analysis of bone counts by maximum likelihood. J. Archaeol. Sci. 27, 111–125.

Rosenlund, K., 1980. Knoglematerialet fra bopladsen Lundby II. In: Henriksen, B.B. (Ed.), Lundby-holmen: Pladser Af Maglemose-type I Sydsjælland. Det Kongelige Nordiske Oldskriftselskab, Copenhagen, pp. 128–142.

Rowley-Conwy, P., 1993. Season and reason: the case for a regional interpretation of Mesolithic settlement patterns. Archeol. Pap. Am. Anthropol. Assoc. 4, 179–188.

Rowley-Conwy, P., 1999. Economic prehistory in southern Scandinavia. In: Coles, J., B, R.M., Mellars, P. (Eds.), World Prehistory: Studies in Memory of Grahame Clark. Oxford University Press, Oxford, pp. 125–159. Proceedings of the British Academy 99.

Sarauw, G., 1903. En stenalders boplats i Maglemose ved Mullerup, sammenholt med beslægtede fund. Aarbøger Nordisk Oldkyndighed og Hist. 1903, 148–315.

Schmölcke, U., Meadows, J., Ritchie, K., Bērziņš, V., Lübke, H., Zagorska, I., 2016. Neolithic fish remains from the freshwater shell midden Riņņukalns in northern Latvia. Environ. Archaeol. 21, 325–333.

Schoeninger, M.J., DeNiro, M.J., 1984. Nitrogen and carbon isotopic composition of bone collagen from marine and terrestrial animals. Geochem. Cosmochim. Acta

48, 625–639.

Selva, N., Hobson, K.A., Cortés-Avizanda, A., Zalewski, A., Donázar, J.A., 2012. Mast pulses shape trophic interactions between fluctuating rodent populations in a primeval forest. PLoS One 7 e51267.

SGU. *Swedish Geological Survey* shoreline displacement map. [Online]. Available: http://maps2.sgu.se/kartgenerator/maporder_sv.html. [Accessed February 2017].

Sims, N.A., Martin, T.J., 2014. Coupling the activities of bone formation and resorption: a multitude of signals within the basic multicellular unit. BoneKEy Rep. 3, 481.

Sjögren, K.-G., Ahlström, T., 2016. Early mesolithic Burials from Bohuslän, western Sweden. In: Grünberg, J.M., Gramsch, B., Larsson, L., Orschiedt, J., Meller, H. (Eds.), Mesolithic Burials – Rites, Symbols and Social Organisation of Early Postglacial Communities. Landesmuseum Halle, Halle, pp. 125–143. International Conference Halle (Saale), Germany, 18th–21st September 2013.

Sponheimer, M., Robinson, T., Ayliffe, L., Roeder, B., Hammer, J., Passey, B., West, A., Cerling, T., Dearing, D., Ehleringer, J., 2003. Nitrogen isotopes in mammalian herbivores: hair δ15N values from a controlled feeding study. Int. J. Osteoarchaeol. 13, 80–87.

Sten, S., Ahlström, T., Alexandersen, V., Borrman, H., Christensen, E., Ekenman, I., Kloboucek, J., Königsson, L.-K., Possnert, G., Ragnesten, U., 2000. Barumkvinnan: nya forskningsrön. Fornvännen 95, 73–87.

Sørensen, L., Karg, S., 2014. The expansion of agrarian societies towards the north–new evidence for agriculture during the Mesolithic/Neolithic transition in Southern Scandinavia. J. Archaeol. Sci. 51, 98–114.

Tauber, H., 1981. 13C evidence for dietary habits of prehistoric man in Denmark. Nature 292, 332–333.

Testart, A., 1982. The significance of food storage among hunter-gatherers: residence patterns, population densities, and social inequalities. Curr. Anthropol. 23, 523–537.

USDA. US Department of Agriculture, Agricultural Research Service, Nutrient Data Laboratory. USDA National Nutrient Database for Standard Reference, Release 28. [Online]. Available: https://ndb.nal.usda.gov/ndb/[Accessed September 2017].

Van Klinken, G.J., Richards, M.P., Hedges, B.E., 2000. An overview of causes for stable isotopic variations in past European human populations: environmental, ecophysiological, and cultural effects. In: Ambrose, S.H., Katzenberg, M.A. (Eds.), Biogeochemical Approaches to Paleodietary Analysis. Kluwer Academic/Plenum Publishers, New York, pp. 39–63.

Vander Zanden, M.J., Cabana, G., Rasmussen, J.B., 1997. Comparing trophic position of freshwater fish calculated using stable nitrogen isotope ratios (δ15N) and literature dietary data. Can. J. Fish. Aquat. Sci. 54, 1142–1158.

Vanderklift, M.A., Ponsard, S., 2003. Sources of variation in consumer-diet δ15N enrichment: a meta-analysis. Oecologia 136, 169–182.

Weatherley, N., 1987. The diet and growth of 0-group dace, Leuciscus leuciscus (L.), and roach, Rutilus rutilus (L.), in a lowland river. J. Fish. Biol. 30, 237–247.

Wheeler, A., Jones, A.K., 1989. Fishes. Cambridge University Press, Cambridge.

Woodman, P.C., 1985a. Excavations at Mount Sandel, 1973-77, County Londonderry. Her Majesty's Stationery Office, Belfast.

Woodman, P.C., 1985b. Mobility in the Mesolithic of northwestern Europe: an alternative explanation. In: Price, D., Brown, J.A. (Eds.), Prehistoric Hunter-Gatherers: the Emergence of Cultural Complexity. Academic Press, Orlando, pp. 325–339.

Yesner, D.R., 1980. Maritime hunter-gatherers: ecology and prehistory. Curr. Anthropol. 21, 727–750.

Zangrando, A.F., 2009. Is fishing intensification a direct route to hunter-gatherer complexity? A case study from the Beagle Channel region (Tierra del Fuego, southern South America). World Archaeol. 41, 589–608.

Supplementary Data

Fish and resilience among Early Holocene foragers of southern Scandinavia: a fusion of stable isotopes and zooarchaeology through Bayesian mixing modelling

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S1: Scandinavian Early and Middle Mesolithic human stable isotope data

S2: Stable isotope data this study.

S3: Stable isotope data other studies.

S4: Protein scaling data

Table S 1 Early (EM) and Middle (MM) Mesolithic human isotope values from Scandinavia. EM= Early Mesolithic, MM= Middle Mesolithic, NA=not available

Individual nr	Time period	Site	Environment	δ13C	δ15N	C:N	Element	Reference	Lab nr	%C	%N	Radiocarbon date
1	EM	Ageröd I, 36895 19	Freshwater	-20,23	10,54	3.282	Femur	This study	COIL 244	42.15	14.98	NA
2	EM	Ageröd I:HC	Freshwater	-19,7	13,8	3.6	Ulna	Eriksson 2003	AGE 02	36.4	11.7	NA
3	EM	Ageröd I:HC	Freshwater	-19,9	10,9	3.4	Femur	Eriksson 2003	AGE 04	40.5	14.1	NA
4	EM	Ageröd I:HC, x0y51	Freshwater	-18,61	13,23	3.336	Humerus juvenile	This study	COIL 245	39.77	13.9	NA
5	EM	Ageröd IA, x-9y30	Freshwater	-18,8	13,2	3.44	Femur juvenile	This study	COIL 241	44.35	15.04	NA
14	EM	Barum	Freshwater	-20,9	12	NA	NA	Sten et al 2004	Ua-10667	NA	NA	7895 ± 75
16	EM	Bredgården	Freshwater	-18,8	11	3.2	Femur	Borrman et al 1995	Ua-6629	NA	NA	8645 ± 95
18	EM	Hanaskede	Freshwater	-19,7	9,9	3.2	Calvarium	Eriksson 2003	HAN03	42.9	15.6	NA
19	EM	Hedegård	Freshwater	-20,3	11,5	3.2	Cranium,	Fischer et al 2007	AAR-8560; AAR-8561	40.4	14.8	8680 ± 40
20	EM	Holmegård	Freshwater	-20	12,4	3.2	Humerus	Fischer et al 2007	AAR-8560/M57435	43.2	15.7	8315 ± 45
21	EM	Holmegård	Freshwater	-20,2	11,6	3.2	Ulna	Fischer et al 2007	AAR-8561	38.3	14	8500 ± 65
22	EM	Holmegård	Freshwater	-18,5	11,8	3.2	Ulna	Fischer et al 2007	AAR-8559	40.8	14.9	NA
23	EM	Holmegård	Freshwater	-18,6	11,8	3.1	Humerus	Fischer et al 2007	AAR-8558	36.7	13.6	8465 ± 35
29	EM	Kams Lummelunda	Freshwater	-17,9	13,4	3.3	NA	Lidén 1996	Lu-1983	44.8	15.7	8050 ± 75
30	EM	Koelbjerg	Freshwater	-22,3	7,9	3.4	Femur	Fischer et al 2007	AAR-8613	42.2-46.3	13.2-15.4	9285 ± 50
31	EM	Kongemose	Freshwater	-22,3	11,5	3.5	Dentes	Fischer et al 2007	AAR6788/A51207,AS40/0	46.2	15.3	8060 ± 65
32	EM	Køge Sønakke	Freshwater	-16,8	12,4	3.3	Humerus	Fischer et al 2007	K-5099	33.1	11.9	8250 ± 85
33	EM	Malmö harbor	Freshwater	-17,08	9,54	3.2	Femur	This study (δ13C=-17.08; δ15N=9.48) Ahlström & Sjögren (δ13C=-17.08; δ15N=9.6) (mean value used)	COIL 290	44.77	16.24	8149±42
34	EM	Mullerup	Freshwater	-21,4	10	3.6	Mandibula	Fischer et al 2007	BCH198: 7	41.9	13.8	NA
35	EM	Mullerup	Freshwater	-18,5	9,7	3.2	Femur	Fischer et al 2007	AAR-8554/NM1 A18269	39.8	14.4	8310 ± 55
38	EM	stora förvar	Freshwater	-17,58	12,13	3.281	Tibia	This study	COIL 384	43.49	15.46	NA
39	EM	stora förvar	Freshwater	-17,81	10,88	3.426	NA	This study	COIL 386	44.63	15.19	NA
40	EM	stora förvar	Freshwater	-19,85	9,73	3.456	NA	This study	COIL 385	43.79	14.78	NA
41	EM	Sunnansund, G31555	Freshwater	-21,85	13,12	3.68	Cranium	This study	UB-23795	NA	NA	7933±36
42	EM	Sunnansund, G21701	Freshwater	-19,95	9,32	3.651	Cranium	This study	COIL 94	9.14	2.92	NA
43	EM	Sunnansund, G 3732	Freshwater	-19,01	13,32	3.41	Phlanx 2	This study	UB-23792	NA	NA	7897±49
49	EM	Tømmerupgårds Mose	Freshwater	-20,9	8,3	3.3	Cranium	Fischer et al 2007	POZ-17031	41.9	14.8	8730 ± 50

52	EM	Övre Vannborga 1.1	Freshwater	-17,46	11,5	3.307	Femur	This study	COIL 405	45.41	16.02	NA
82	EM	Kams Lummelunda	Freshwater	-19,1	13,2	3.3	NA	Lidén 1996		40.7	14.5	
24	EM	Huseby Klev	Marine	-15,7	15,9	3.3	Cranium	Eriksson 2003	HUS03	39.9	14.1	(8560± 75)
25	EM	Huseby Klev	Marine	-15,1	13,9	3.4	Femur	Eriksson 2003	HUS05	39.7	13.6	preboreal
26	EM	Huseby Klev	Marine	-15,8	15,4	3.3	Cranium	Eriksson 2003	HUS04	37.7	13.3	preboreal
27	EM	Huseby Klev	Marine	-15,6	14,7	3.5	maxilla	Eriksson 2003	HUS02	42	14.1	preboreal
28	EM	Huseby klev	Marine	-15,56	15,32	3.523	Cranium	This study	COIL 314	46.61	15.43	preboreal
37	EM	Skibevall	Marine	-16,38	15,47	3.39	Cranium	This study (δ13C=-16.47; δ15N=15.44), Ahlström & Sjögren (δ13C=-16.29; δ15N=15.5) (mean value used)	COIL 289, UBA-23145	44.93	15.46	8437±56 bp
51	EM	Österöd	Marine	-17,23	14,17		Dentes	Ahlström Sjögren	UBA-14094	NA	NA	8950±42 (8972±36)
6	MM	Alvastra	Freshwater	-18,2	11,6	3.4	Mandibula	Fornander 2011	ALM 03	41.6	14.4	7088±62
15	MM	Blak	Freshwater	-17,9	12,8	3.5	Mandibula	Fischer et al 2007	Ka-6454/ACQ59: 23+36	37.1	12.4	7440 ± 90
53	MM	Motala kanaljorden, individual 1	Freshwater	-16,95	12,75	3.25	Cranium, Temporale (mean value)	Eriksson et al 2016	MKA 03+82	39.7	14.35	6701±64
54	MM	Motala kanaljorden, individual 2	Freshwater	-20,35	11,9	3.35	Cranium, Parietale (mean value)	Eriksson et al 2016	MKA 23+84	34.7	12.15	6734±30
55	MM	Motala kanaljorden, individual 3	Freshwater	-19,3	13	3.2	Cranium	Eriksson et al 2016	MKA 05	39.7	14.5	6877±69
56	MM	Motala kanaljorden, individual 4	Freshwater	-16,8	13,3	3.2	Maxilla	Eriksson et al 2016	MKA 06	40.6	14.7	6842±68
57	MM	Motala kanaljorden, individual 5a	Freshwater	-17,4	12,6	3.2	Maxilla	Eriksson et al 2016	MKA 74	38.5	13.9	6677±3
58	MM	Motala kanaljorden, individual 5b	Freshwater	-18	12,3	3.3	Cranium	Eriksson et al 2016	MKA 07	35.8	12.8	6915±93
59	MM	Motala kanaljorden, individual 6	Freshwater	-16,8	13,3	3.2	Zygomaticum	Eriksson et al 2016	MKA 08	39.6	14.4	6863±75
60	MM	Motala kanaljorden, individual 7	Freshwater	-17,7	12,3	3.2	Cranium	Eriksson et al 2016	MKA 09	39.5	14.3	7013±76
61	MM	Motala kanaljorden, individual 8	Freshwater	-19	12,9	3.2	Dens (P2)	Eriksson et al 2016	MKA 35	39.6	14.3	NA
62	MM	Motala kanaljorden, 9	Freshwater	-19,2	12,3	3.3	Cranium	Eriksson et al 2016	MKA 11	40.6	14.4	6919±64
63	MM	Motala kanaljorden, individual 12	Freshwater	-17,1	13,1	3.2	Mandibula	Eriksson et al 2016	MKA 13	30.9	11.1	7212±109 6773±30
64	MM	Motala kanaljorden, Skull AA	Freshwater	-17,53	12,7	3.2	Occ,Par,Temp, (mean value)	Eriksson et al 2016	MKA 14, 75, 80	39.4	14.43	NA
65	MM	Motala kanaljorden, Skull BB	Freshwater	-17	13,35	3.2	Frontale, Parietale (mean value)	Eriksson et al 2016	MKA 76, 79	42.2	15.45	6836±32

66	MM	Motala kanaljorden, Ulna	Freshwater	-17,9	13,2	3.2	Ulna	Eriksson et al 2016	MKA 77	42.3	15.4	6965±31
67	MM	Motala kanaljorden, femur MKA 78	Freshwater	-17,2	12,2	3.2	Femur	Eriksson et al 2016	MKA 78	40	14.6	6758±32
68	MM	Motala kanaljorden, Parietale MKA 81	Freshwater	-17,9	12,5	3.3	Parietale	Eriksson et al 2016	MKA 81	37.8	13.5	6770±31
69	MM	Motala kanaljorden, femur MKA 02	Freshwater	-17,3	12	3.3	Femur	Eriksson et al 2016	MKA 02	42.7	15.2	6837±41
70	MM	Motala kanaljorden, MKA 01	Freshwater	-17,3	11,6	3.3	Femur	Eriksson et al 2016	MKA 01	33.9	12.1	NA
71	MM	Motala kanaljorden, parietale MKA 83	Freshwater	-16,7	13,5	3.2	parietale	Eriksson et al 2016	MKA 83	42.4	15.6	6896±31
72	MM	Motala Strandvägen, grave 7	Freshwater	-18,9	12,4	3.2	Femur	Eriksson et al 2016	MOT 059	42.4	15.3	6739±62
73	MM	Motala Strandvägen, grave 11	Freshwater	-17,2	12,6	3.3	Tibia	Eriksson et al 2016	MOT 060	44.1	15.7	6392±62
74	MM	Motala Strandvägen, grave 13	Freshwater	-17,5	12,3	3.3	Naviculare	Eriksson et al 2016	MOT 062	42.5	15.2	6823±64
75	MM	Motala Strandvägen, grave 16	Freshwater	-17,6	11,9	3.3	Femur	Eriksson et al 2016	MOT 120	38.9	13.6	6274±40
76	MM	Motala Strandvägen, G200657,	Freshwater	-21,5	12,3	3.3	Tibia	Eriksson et al 2016	MOT 067	43.7	15.4	7118±57
77	MM	Motala Strandvägen, G20226	Freshwater	-18,1	11,7	3.4	Femur sin	Eriksson et al 2016	MOT 069	43.3	15	6799±92
78	MM	Motala Strandvägen, G2407 femur	Freshwater	-18,1	11,1	3.3	Femur dx	Eriksson et al 2016	MOT 070	44	15.7	6565±61
79	MM	Motala Strandvägen, G2407 temporale	Freshwater	-18,1	11,3	3.4	Temporale	Eriksson et al 2016	MOT 071	44.4	15.3	6795±64
80	MM	Motala kanaljorden, individual 5c	Freshwater	-19,7	12,2	3.1	Dens (M2)	Eriksson et al 2016	MKA 31	40.8	15.2	NA
81	MM	Motala kanaljorden, individual 5d	Freshwater	-20	11,3	3.2	Dens (M3)	Eriksson et al 2016	MKA 34	39.9	14.7	NA
7	MM	Argus	Marine	-15,1	16,9	3.3	Femur	Fischer et al 2007	AAR-8856	46.5	16.2	NA
8	MM	Argus	Marine	-16,3	12,7	3.2	Tibia	Fischer et al 2007	F 58-54 b	44.2	16	NA
9	MM	Argus	Marine	-15,2	16,9	3.3	Tibia	Fischer et al 2007	BCH198: 32a+b	40.7	14.5	NA
10	MM	Argus	Marine	-14,5	13,4	3.4	Humerus	Fischer et al 2007	AAR-8858	42.9	14.9	NA
11	MM	Argus	Marine	-17,3	13,5	3.4	Humerus	Fischer et al 2007	AAR-8859	28.8	10	NA
12	MM	Argus	Marine	-14,3	12,8	3.3	Humerus	Fischer et al 2007	K-4354/AS 7/01, F 58-54	44.2	15.7	7080 ± 75
13	MM	Argus	Marine	-15,2	14,8	3.4	Femur	Fischer et al 2007	AAR-8857	38.4	13.4	NA
17	MM	Dyrholm	Marine	-10,8	13,3	3.3	Calvarium,	Fischer et al 2007	Poz-17034/ACQ59: 16+26	39.2	13.9	6680 ± 50
36	MM	Måkläppen	Marine	-15,8	13,95	3.317	Femur	This study	COIL 404	42.73	15.03	7100±50
44	MM	Tybrind Vig	Marine	-11,5	16,3	3.3	Mandibula	Fischer et al 2007	AAR-9341/AAR-9341	41	14.6	6820 ± 55
45	MM	Tybrind Vig	Marine	-14,7	16,4	3.3	Pars petrosum	Fischer et al 2007	BCH198: 27a+b	36.6	12.9	NA

46	MM	Tybrind Vig	Marine	-15,7	13,4	3.5	Femur	Fischer et al 2007	K-3558/BCH195: 20+36	37.9	12.8	6740 ± 80
47	MM	Tybrind Vig	Marine	-11,1	16,3	3.3	Costae	Fischer et al 2007	AAR-9342/AAR-9342	39.8	14.3	6905 ± 55
48	MM	Tågerup	Marine	-19,94	12,9	3.232	Femur	This study	COIL 288	44.42	16.03	NA
50	MM	Uleberg	Marine	-16,4	15,2	3.3	Long bone	Eriksson 2003	Ua-7838	28.8	10.2	6890±100, 6630±75

Table S 2 Isotope data this study. F=Freshwater; M=Marine; PIK=northern pike; FAM= freshwater aquatic mammal; FCA=freshwater catadromous/anadromous fish; THE= terrestrial herbivores; MHF=marine high trophic fish; CYP=cyprinids; MLF=marine low trophic fish; MAM=marine aquatic mammal; MCA= marine catadromous/anadromous fish; FMF=freshwater mid trophic fish; TOM=terrestrial omnivores; with BER=berries; FRU=fruits; HAZ=hazelnuts; MUS=mushrooms; NI=Not included in study;

Lab Id number (COIL)	Site name	Environment	Culture epoch	Taxon	Source Code	Fragments	Element	δ13C	δ15N	C:N	%C	%N	% Collagen	Layer	Context	Bone for collagen extraction (mg)	Extracted collagen (mg)	Analysed Collagen (mg)	Bone sample weight (g)
~~1~~	~~Ringsjöholm~~	~~F~~	~~MM~~	~~Capreolus capreolus~~	~~THE~~	~~1~~	~~Astr~~	-	-	-			~~0,04%~~		~~2414:5~~	250	0,1	~~0~~	~~0,7~~
~~2~~	~~Ringsjöholm~~	~~F~~	~~MM~~	~~Bos primigenius~~	~~THE~~	~~1~~	~~Astr~~	-	-	-			NA	~~på sanden~~	~~121~~	250,3			~~2,5~~
3	Ringsjöholm	F	MM	Alces alces	THE	1	Hum	-23.21	3.82	3.37	39.47	13.66	5,39%		807	250,5	13,5	1,064	1,9
~~4~~	~~Ringsjöholm~~	~~F~~	~~MM~~	~~Castor fiber~~	~~THE~~	~~1~~	~~Mand~~	~~-26.92~~			~~4.44~~		~~0,20%~~		~~3325:1~~	250,6	0,5	~~0,212~~	~~0,75~~
~~5~~	~~Ringsjöholm~~	~~F~~	~~MM~~	~~Cervus elaphus~~	~~THE~~	~~1~~	~~Cox~~	-	-	-	-	-	NA		~~1072~~	251,1		-	~~1,6~~
~~6~~	~~Ringsjöholm~~	~~F~~	~~MM~~	~~Canis familiaris~~	~~NI~~	~~1~~	~~ax~~	-			-		NA	-	~~2698:3~~	250,8		-	~~0,74~~
~~7~~	~~Ringsjöholm~~	~~F~~	~~MM~~	~~Sus scrofa~~	~~TOM~~	~~1~~	~~Scap~~						NA		~~3297:2~~	250,4			~~1,7~~
~~8~~	~~Ringsjöholm~~	~~F~~	~~MM~~	~~Esox lucius~~	~~PIK~~	~~1~~	~~Vert~~						NA		~~3615:5~~	124,9			~~1,1~~
~~9~~	~~Ringsjöholm~~	~~F~~	~~MM~~	~~Esox lucius~~	~~PIK~~	2	~~Vert~~						NA		~~3420:15~~				~~0,15~~
~~10~~	~~Ringsjöholm~~	~~F~~	~~MM~~	~~Cyprinidae~~	~~CYP~~	~~3~~	~~Phar~~						NA		~~3420:15~~	146,1			~~0,16~~
~~11~~	~~Ringsjöholm~~	~~F~~	~~MM~~	~~Cyprinidae~~	~~CYP~~	2	~~Vert~~						NA		~~3420:15~~	84,9			~~0,13~~
~~12~~	~~Ringsjöholm~~	~~F~~	~~MM~~	~~Perca fluviatilis~~	~~FMF~~	4	~~Vert~~						NA		~~3420:15~~	165,5			~~0,2~~
~~13~~	~~Ringsjöholm~~	~~F~~	~~MM~~	~~Anguilla anguilla~~	~~FCA~~	~~5~~	~~Vert~~						0,00%		~~3420:15~~	87,4	0		~~0,11~~
~~14~~	~~Ringsjöholm~~	~~F~~	~~MM~~	~~Perca fluviatilis~~	~~FMF~~	~~5~~	~~Vert~~	~~-27.02~~	~~-4.61~~	~~11.43~~	~~35.77~~	~~3.65~~	~~0,37%~~		~~2695:1~~	109,2	0,4	~~0,11~~	~~0,15~~
~~15~~	~~Ageröd V~~	~~F~~	~~MM~~	~~Capreolus capreolus~~	~~THE~~	~~1~~	~~Scap~~	~~-25.5~~	~~4.94~~	~~6.569~~	~~51.47~~	~~9.14~~	~~2,79%~~		~~x15y14 g7 18~~	193,5	5,4	~~0,999~~	~~0,83~~
~~16~~	~~Ageröd V~~	~~F~~	~~MM~~	~~Perca fluviatilis~~	~~FMF~~	~~3~~	~~Vert~~	~~-26.84~~	~~4.31~~	~~11.03~~	~~45.82~~	~~4.84~~	~~0,87%~~			196,1	1,7	~~0,885~~	~~0,2~~
17	Ageröd V	F	MM	Tinca tinca	CYP	1	Hyo.mand	-21.87	5.82	3.631	42.35	13.6	0,64%			251,2	1,6	1,033	0,33
~~18~~	~~Ageröd V~~	~~F~~	~~MM~~	~~Cyprinidae~~	~~CYP~~	~~3~~	~~Vert~~	~~-24.09~~	~~5.01~~	~~4.111~~	~~42.19~~	~~11.97~~	~~0,22%~~			180,6	0,4	~~0,222~~	~~0,22~~
~~19~~	~~Ageröd V~~	~~F~~	~~MM~~	~~Esox lucius~~	~~PIK~~	~~1~~	~~Denta~~	~~-23.63~~	~~2.3~~	~~4.613~~	~~38.72~~	~~9.79~~	~~0,04%~~			251,9	0,1	~~0,073~~	~~0,36~~
20	Ageröd V	F	MM	Cervus elaphus	THE	1	M.tars	-22.72	3.63	3.326	42.93	15.05	6,85%		6343	251	17,2	1,04	2,1
21	Ageröd V	F	MM	Sus scrofa	TOM	1	Tib	-22.12	4.93	3.45	42.48	14.36	5,81%		5440	251,1	14,6	1,017	0,91
22	Ageröd V	F	MM	Lutra lutra	NI	1	Fem	-23.45	11.45	3.441	43.84	14.86	4,07%		7	250,9	10,2	0,99	0,64
23	Ageröd V	F	MM	Alces alces	THE	1	Hum	-22.53	3.86	3.411	44.38	15.17	7,16%		113	251,3	18	1,034	1,3

~~24~~	~~Ageröd I:HC~~	~~F~~	~~EM~~	~~Bos primigenius~~	~~THE~~	~~1~~	~~Ph 2~~	~~-26.03~~	~~2.53~~	~~16.35~~	~~52.48~~	~~3.74~~	~~0,20%~~			250,9	0,5	~~0,469~~	~~1,7~~
~~25~~	~~Ageröd I:HC~~	~~F~~	~~EM~~	~~Sus scrofa~~	~~TOM~~	~~1~~	~~Calc~~	~~-25.46~~	-	-	~~34.81~~	-	~~0,04%~~	~~övre torv~~		250,4	0,1	~~0,031~~	~~2,8~~
~~26~~	~~Ageröd I:HC~~	~~F~~	~~EM~~	~~Cervus elaphus~~	~~THE~~	~~1~~	~~Scap~~	~~-22.36~~	~~2.71~~	~~3.712~~	~~44.41~~	~~13.95~~	~~4,39%~~	~~övre torv~~		250,5	11	~~1,025~~	~~0,83~~
~~27~~	~~Ageröd I:HC~~	~~F~~	~~EM~~	~~Alces alces~~	~~THE~~	~~1~~	~~Cp2+3~~	~~-22.66~~	~~4.08~~	~~3.728~~	~~43~~	~~13.45~~	~~2,63%~~	~~övre torv~~		250,7	6,6	~~1,067~~	~~2,61~~
~~28~~	~~Ageröd I:HC~~	~~F~~	~~EM~~	~~Capreolus capreolus~~	~~THE~~	~~1~~	~~Hum~~	~~-24.94~~	~~4.46~~	~~4.802~~	~~48.17~~	~~11.7~~	~~2,60%~~	~~undre torv~~		250,4	6,5	~~1,074~~	~~0,8~~
~~29~~	~~Ageröd I:HC~~	~~F~~	~~EM~~	~~Bos primigenius~~	~~THE~~	~~1~~	~~Ph 1~~	~~-23.97~~	~~4.86~~	~~4.087~~	~~46.47~~	~~13.26~~	~~3,79%~~	~~vita lagret~~		250,4	9,5	~~1,012~~	~~1,56~~
~~30~~	~~Tågerup 1:1~~	~~M~~	~~MM~~	~~Lutra lutra~~	~~NI~~	~~1~~	~~Mand~~	~~-25.67~~	~~-15.5~~	~~6.835~~	~~4.45~~	~~0.76~~	~~0,08%~~	~~8~~	~~R1746~~	249,1	0,2	~~0,273~~	~~1,6~~
31	Tågerup 1:1	M	MM	Alces alces	THE	1	Tib	-22.65	4.7	3.438	38.95	13.21	1,28%	4	R2129	249,3	3,2	1,009	0,72
~~32~~	~~Tågerup 1:1~~	~~M~~	~~MM~~	~~Canis familiaris~~	~~NI~~	~~1~~	~~Fem~~	~~-24.93~~	~~-13.2~~	~~6.901~~	~~3.88~~	~~0.65~~	~~0,20%~~	~~8~~	~~R2489~~	250,6	0,5	~~0,426~~	~~1,2~~
33	Tågerup 1:1	M	MM	Canis familiaris	NI	1	Fem	-19.69	11.33	3.277	42.14	14.99	2,40%	4	R2142	249,6	6	0,988	1
34	Tågerup 1:1	M	MM	Halichoerus grypus	MAM	1	Mand	-13.24	16.23	3.564	40.27	13.17	1,52%	4	R2099	250,2	3,8	0,994	1,3
35	Tågerup 1:1	M	MM	Halichoerus grypus	MAM	1	M.tars1	-14.73	17.94	3.187	41.35	15.13	3,68%	4	R1461	250,3	9,2	0,995	1,5
36	Tågerup 1:1	M	MM	Halichoerus grypus	MAM	1	Rad	-13.16	16.6	3.418	39.53	13.49	1,24%	4	22235	249,9	3,1	1,047	1,3
37	Tågerup 1:1	M	MM	Cervus elaphus	THE	1	Tib	-23.49	3.98	3.325	42.63	14.95	5,73%	22	R3053	249,7	14,3	0,978	1,5
~~38~~	~~Tågerup 1:1~~	~~M~~	~~MM~~	~~Sus scrofa~~	~~TOM~~	~~1~~	~~Mand~~	-	-	-	-	-	NA	~~8~~	~~R2063~~	250,4		-	~~1,8~~
~~39~~	~~Tågerup 1:1~~	~~M~~	~~MM~~	~~Clupea harengus~~	~~MLF~~	~~20~~	~~Vert~~	~~-18.04~~	~~10.42~~	~~3.805~~	~~39.27~~	~~12.04~~	~~0,35%~~	~~4~~	~~R2049~~	142,8	0,5	~~0,361~~	~~0,14~~
~~40~~	~~Tågerup 1:1~~	~~M~~	~~MM~~	~~Gadus morhua~~	~~MHF~~	~~4~~	~~Vert~~						NA	~~8~~	~~R2375~~	249,8			~~0,4~~
~~41~~	~~Tågerup 1:1~~	~~M~~	~~MM~~	~~Anguilla anguilla~~	~~MCA~~	~~3~~	~~Vert~~	-	-	-	-	-	NA	~~4~~	~~R2432~~	45,7		-	~~0,03~~
42	Tågerup 1:1	M	MM	Capreolus capreolus	THE	1	Rad	-23.59	4.18	3.255	42.34	15.17	2,52%	4	R2081	250,4	6,3	0,982	2,3
~~43~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Cyprinidae~~	~~CYP~~	~~10~~	~~Vert~~	~~-23.3~~	~~7.9~~	~~7.583~~	~~10.14~~	~~1.56~~	NA	~~111~~	~~31525~~	NA	NA	~~0,895~~	~~0,7~~
~~44~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Cyprinidae~~	~~CYP~~	~~12~~	~~Vert~~	~~-20.02~~	~~5.9~~	~~3.838~~	~~5.61~~	~~1.7~~	NA	~~111~~	~~16795~~	NA	NA	~~0,82~~	~~0,5~~
~~45~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Cyprinidae~~	~~CYP~~	~~3~~	~~Vert~~	~~-19.72~~	~~6.09~~	~~3.733~~	~~10.22~~	~~3.19~~	NA	~~111~~	~~16795~~	NA	NA	~~0,987~~	~~0,5~~
~~46~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Cyprinidae~~	~~CYP~~	~~12~~	~~Vert~~	~~0~~	~~0~~	~~0~~	~~0~~	~~0~~	NA	~~111~~	~~14984~~	NA	NA	~~0,08~~	~~0,4~~
~~47~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Cyprinidae~~	~~CYP~~	~~5~~	~~Vert~~	~~-19.88~~	~~7.88~~	~~4.293~~	~~8.28~~	~~2.25~~	NA	~~111~~	~~15914~~	NA	NA	~~0,702~~	~~0,5~~
48	Sunnansund	F	EM	Anguilla anguilla	FCA	16	Vert	-19.51	8.18	3.651	14.02	4.47	NA	111	16795	NA	NA	0,895	0,4
49	Sunnansund	F	EM	Anguilla anguilla	FCA	10	Vert	-20.1	7.09	3.605	13.33	4.3	NA	111	16940	NA	NA	1,029	0,3
50	Sunnansund	F	EM	Anguilla anguilla	FCA	11	Vert	-21.17	7.11	3.581	9.43	3.07	NA	111	15914	NA	NA	0,951	0,3
~~51~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Perca fluviatilis~~	~~FMF~~	~~8~~	~~Vert~~	~~-22.33~~	~~6.99~~	~~6.218~~	~~5.94~~	~~1.11~~	NA	~~111~~	~~14984~~	NA	NA	~~0,904~~	~~0,4~~
52	Sunnansund	F	EM	Perca fluviatilis	FMF	2	Vert	-23.25	4.79	3.64	15.68	5.01	NA	111	16795	NA	NA	0,839	0,4
~~53~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Perca fluviatilis~~	~~FMF~~	~~16~~	~~Vert~~	~~-18.88~~	~~7.07~~	~~4.001~~	~~7.48~~	~~2.17~~	NA	~~111~~	~~15914~~	NA	NA	~~0,707~~	~~0,4~~
~~54~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Perca fluviatilis~~	~~FMF~~	~~5~~	~~Vert~~	~~-25.76~~	~~7.8~~	~~10.13~~	~~4.37~~	~~0.5~~	NA	~~111~~	~~27741~~	NA	NA	~~0,99~~	~~0,4~~
~~55~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Perca fluviatilis~~	~~FMF~~	~~12~~	~~Vert~~	~~-19.91~~	~~9.92~~	~~4.118~~	~~7.86~~	~~2.22~~	NA	~~111~~	~~16940~~	NA	NA	~~0,823~~	~~0,5~~
56	Sunnansund	F	EM	Rutilus rutilus	CYP	1	Phar	-16.51	6.98	3.605	8.06	2.6	NA	111	16795	NA	NA	0,827	0,3
57	Sunnansund	F	EM	Rutilus rutilus	CYP	4	Phar	-17.38	4.98	3.5	12.38	4.12	NA	111	16795	NA	NA	0,961	0,4
~~58~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Rutilus rutilus~~	~~CYP~~	~~3~~	~~Phar~~	~~-21.37~~	~~6.83~~	~~5.355~~	~~9.45~~	~~2.05~~	NA	~~111~~	~~31525~~	NA	NA	~~0,82~~	~~0,4~~
~~59~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Rutilus rutilus~~	~~CYP~~	~~3~~	~~Phar~~	~~-18.7~~	~~6.17~~	~~4.83~~	~~8.85~~	~~2.13~~	NA	~~111~~	~~14984~~	NA	NA	~~1,036~~	~~0,4~~
~~60~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Rutilus rutilus~~	~~CYP~~	~~5~~	~~Phar~~	~~-19.36~~	~~6.74~~	~~3.931~~	~~6.92~~	~~2.05~~	NA	~~111~~	~~14960~~	NA	NA	~~0,77~~	~~0,3~~
61	Sunnansund	F	EM	Rutilus rutilus	CYP	6	Phar	-18.6	6.28	3.64	11.16	3.57	NA	111	16940	NA	NA	0,988	0,4

62	Sunnansund	F	EM	Tinca tinca	CYP	4	Phar	-18.5	6.68	3.465	13.26	4.46	NA	111	16940	NA	NA	1,457	0,3
~~63~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Squalius cephalus~~	~~CYP~~	~~2~~	~~Phar~~	~~-16.84~~	~~6.23~~	~~3.861~~	~~7.96~~	~~2.4~~	NA	~~111~~	~~16795~~	NA	NA	~~0,758~~	~~0,1~~
64	Sunnansund	F	EM	Abramis brama	CYP	5	Phar	-19.44	6.94	3.395	8.96	3.07	NA	111	16795	NA	NA	0,718	0,2
~~65~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Lota lota~~	~~FMF~~	~~6~~	~~Vert~~	~~-20.76~~	~~6.57~~	~~3.838~~	~~3.37~~	~~1.02~~	NA	~~111~~	~~16795~~	NA	NA	~~0,929~~	~~0,3~~
~~66~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Lota lota~~	~~FMF~~	~~2~~	~~Vert~~	~~-20.93~~	~~7.06~~	~~4.526~~	~~5.07~~	~~1.3~~	NA	~~111~~	~~16795~~	NA	NA	~~0,85~~	~~0,2~~
~~67~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Lota lota~~	~~FMF~~	~~3~~	~~Vert~~	~~-19.77~~	~~8.09~~	~~4.445~~	~~6.2~~	~~1.62~~	NA	~~111~~	~~16940~~	NA	NA	~~0,893~~	~~0,3~~
~~68~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Lota lota~~	~~FMF~~	~~5~~	~~Vert~~	-	-	~~0~~	-	-	NA	~~111~~	~~16940~~	NA	NA	-	~~0,2~~
~~69~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Lota lota~~	~~FMF~~	~~3~~	~~Vert~~	~~-20.87~~	~~5.75~~	~~4.62~~	~~2.86~~	~~0.72~~	NA	~~111~~	~~15914~~	NA	NA	~~0,975~~	~~0,3~~
~~70~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Esox lucius~~	~~PIK~~	~~1~~	~~Denta~~	~~-24.49~~	~~9.29~~	~~7.07~~	~~12.48~~	~~2.05~~	NA	~~111~~	~~15914~~	NA	NA	~~1,014~~	~~0,5~~
~~71~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Esox lucius~~	~~PIK~~	~~1~~	~~Cleit~~	~~-22.07~~	~~10.09~~	~~4.806~~	~~8.26~~	~~2~~	NA	~~111~~	~~15914~~	NA	NA	~~0,868~~	~~1,1~~
72	Sunnansund	F	EM	Esox lucius	PIK	1	Vert	-18.47	10.84	3.558	14.61	4.78	NA	111	16513	NA	NA	0,893	0,7
~~73~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Esox lucius~~	~~PIK~~	~~5~~	~~Vert~~	-	-	~~0~~	-	-	NA	~~111~~	~~16049~~	NA	NA	-	~~0,4~~
~~74~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Esox lucius~~	~~PIK~~	~~6~~	~~Vert~~	~~-20.68~~	~~8.66~~	~~3.873~~	~~7.48~~	~~2.24~~	NA	~~111~~	~~16795~~	NA	NA	~~0,916~~	~~0,4~~
~~75~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Coregonus~~	~~FMF~~	~~6~~	~~Vert~~	~~-19.38~~	~~6.95~~	~~3.815~~	~~4.58~~	~~1.39~~	NA	~~111~~	~~16795~~	NA	NA	~~1,033~~	~~0,2~~
76	Sunnansund	F	EM	Sander lucioperca	FMF	5	Vert	-19.93	7.39	3.628	8.72	2.8	NA	111	16795	NA	NA	0,815	0,3
~~77~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Sander lucioperca~~	~~FMF~~	~~1~~	~~Vert~~	-	-	~~0~~	-	-	NA	~~111~~	~~31525~~	NA	NA	-	~~0,4~~
~~78~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Tinca tinca~~	~~CYP~~	~~1~~	~~Phar~~	-	-	~~0~~	-	-	NA	~~ferment~~	~~19313~~	NA	NA	-	~~0,4~~
79	Sunnansund	F	EM	Leuciscus idus	CYP	1	Phar	-17.44	6.69	3.033	6.05	2.32	NA	ferment	19313	NA	NA	0,93	0,3
~~80~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Squalius cephalus~~	~~CYP~~	~~3~~	~~Phar~~	~~-18.36~~	~~4.66~~	~~4.025~~	~~6.56~~	~~1.89~~	NA	~~ferment~~	~~19313~~	NA	NA	~~0,797~~	~~0,2~~
81	Sunnansund	F	EM	Abramis brama	CYP	5	Phar	-17.18	6.53	3.535	5.81	1.91	NA	ferment	19313	NA	NA	0,761	0,2
82	Sunnansund	F	EM	Rutilus rutilus	CYP	4	Phar	-17.68	6.97	3.406	10.82	3.7	NA	ferment	19313	NA	NA	0,787	0,4
~~83~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Lota lota~~	~~FMF~~	~~4~~	~~Vert~~	~~-20.83~~	~~7.19~~	~~4.281~~	~~6.55~~	~~1.78~~	NA	~~ferment~~	~~19313~~	NA	NA	~~0,756~~	~~0,3~~
~~84~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Anguilla anguilla~~	~~FCA~~	~~10~~	~~Vert~~	~~-20.7~~	~~6.54~~	~~3.885~~	~~9.45~~	~~2.83~~	NA	~~ferment~~	~~19313~~	NA	NA	~~0,996~~	~~0,3~~
~~85~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Esox lucius~~	~~PIK~~	~~3~~	~~Vert~~	-	-	~~0~~	-	-	NA	~~ferment~~	~~19313~~	NA	NA	-	~~0,6~~
~~86~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Perca fluviatilis~~	~~FMF~~	~~15~~	~~Vert~~	~~-19.27~~	~~7.36~~	~~3.71~~	~~6.59~~	~~2.07~~	NA	~~ferment~~	~~19313~~	NA	NA	~~0,939~~	~~0,3~~
~~87~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Esox lucius~~	~~PIK~~	~~1~~	~~Vert~~	~~-22.35~~	~~3.38~~	~~4.538~~	~~26.35~~	~~6.76~~	NA	~~110~~	~~13909~~	NA	NA	~~0,864~~	~~1,6~~
~~88~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Perca fluviatilis~~	~~FMF~~	~~6~~	~~Vert~~	~~-25.31~~	~~2.85~~	~~8.528~~	~~4.56~~	~~0.62~~	NA	~~110~~	~~13909~~	NA	NA	~~0,747~~	~~0,4~~
~~89~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Perca fluviatilis~~	~~FMF~~	~~12~~	~~Vert~~	~~-25.26~~	~~5.18~~	~~10.46~~	~~8.84~~	~~0.98~~	NA	~~110~~	~~14971~~	NA	NA	~~0,555~~	~~0,4~~
~~90~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Cyprinidae~~	~~CYP~~	~~7~~	~~Vert~~	~~-25.79~~	~~5.98~~	~~15.36~~	~~11.83~~	~~0.89~~	NA	~~110~~	~~14971~~	NA	NA	~~2,35~~	~~0,4~~
~~91~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Sander lucioperca~~	~~FMF~~	~~2~~	~~Vert~~	~~-25.88~~	~~6.61~~	~~14.16~~	~~7.88~~	~~0.64~~	NA	~~110~~	~~21704~~	NA	NA	~~1,108~~	~~0,7~~
~~92~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Esox lucius~~	~~PIK~~	4	~~Vert~~	~~-25.71~~	~~5.48~~	~~19.01~~	~~12.09~~	~~0.74~~	NA	~~110~~	~~21704~~	NA	NA	~~0,934~~	~~0,6~~
~~93~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Homo sapiens~~		~~1~~	~~Mand~~	~~-24.68~~	~~8~~	~~15.57~~	~~20.86~~	~~1.56~~	NA	~~110~~	~~5854~~	NA	NA	~~0,775~~	~~0,8~~
94	Sunnansund	F	EM	Homo sapiens		1	Cra	-19.95	9.32	3.651	9.14	2.92	NA	110	21701	NA	NA	0,906	0,5
~~95~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Halichoerus grypus~~	~~FAM~~	~~1~~	~~Cra~~	~~-23.4~~	~~11.77~~	~~10.04~~	~~17.56~~	~~2.03~~	NA	~~111~~	~~21866~~	NA	NA	~~0,774~~	~~0,7~~
~~96~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Halichoerus grypus~~	~~FAM~~	~~1~~	~~Cra, bulla~~	~~-20~~	~~13.51~~	~~4.34~~	~~21.74~~	~~5.83~~	NA	~~111~~	~~14984~~	NA	NA	~~0,757~~	~~0,7~~
~~97~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Halichoerus grypus~~	~~FAM~~	~~1~~	~~Tib~~	~~-21.34~~	~~8.56~~	~~7.093~~	~~7.55~~	~~1.24~~	NA	~~111~~	~~21726~~	NA	NA	~~0,627~~	~~0,7~~
~~98~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Halichoerus grypus~~	~~FAM~~	~~1~~	~~Cra~~	~~-24.78~~	~~8.4~~	~~16.22~~	~~14.01~~	~~1~~	NA	~~111~~	~~28738~~	NA	NA	~~0,714~~	~~1~~
~~99~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Halichoerus grypus~~	~~FAM~~	~~1~~	~~Cra~~	~~-21.4~~	~~13.82~~	~~4.853~~	~~12.06~~	~~2.89~~	NA	~~111~~	~~19458~~	NA	NA	~~0,877~~	~~0,7~~

~~100~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Pusa hispida~~	~~FAM~~	~~1~~	~~Ulna~~	~~-20.57~~	~~12.11~~	~~4.06~~	~~13.81~~	~~3.96~~	NA	~~111~~	~~16513~~	NA	NA	~~0,975~~	~~0,8~~
~~101~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Castor fiber~~	~~THE~~	~~1~~	~~Tib~~	~~-23.22~~	~~4.96~~	~~4.13~~	~~21.41~~	~~6.03~~	NA	~~111~~	~~19458~~	NA	NA	~~1,083~~	~~0,7~~
~~102~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Pusa hispida~~	~~FAM~~	~~1~~	~~Cox~~	~~-21.08~~	~~13.3~~	~~4.526~~	~~20.09~~	~~5.16~~	NA	~~111~~	~~17342~~	NA	NA	~~0,9~~	~~0,5~~
~~103~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Pusa hispida~~	~~FAM~~	~~1~~	~~Cra~~	~~-22.75~~	~~11.98~~	~~6.3~~	~~18.09~~	~~3.34~~	NA	~~111~~	~~21705~~	NA	NA	~~0,627~~	~~0,6~~
104	Sunnansund	F	EM	Pusa hispida	FAM	1	Atlas	-20.1	9.46	3.313	20.13	7.06	NA	111	21896	NA	NA	0,776	0,5
~~105~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Ursus arctos~~	~~TOM~~	~~1~~	~~Costae~~	~~-25.26~~	~~7.05~~	~~11.49~~	~~4.77~~	~~0.48~~	NA	~~111~~	~~24631~~	NA	NA	~~0,897~~	~~0,7~~
~~106~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Vulpes vulpes~~	~~NI~~	~~1~~	~~Rad~~	~~-21.85~~	~~8.12~~	~~5.238~~	~~21.48~~	~~4.77~~	NA	~~111~~	~~25318~~	NA	NA	~~0,881~~	~~0,4~~
~~107~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Canis familiaris~~	~~NI~~	~~1~~	~~Fem~~	~~-23.15~~	~~4.37~~	~~4.363~~	~~11.48~~	~~3.07~~	NA	~~111~~	~~16897~~	NA	NA	~~0,771~~	~~0,6~~
~~108~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Canis familiaris~~	~~NI~~	~~1~~	~~Tib~~	~~-24~~	~~5.05~~	~~8.003~~	~~17.42~~	~~2.53~~	NA	~~111~~	~~31522~~	NA	NA	~~0,808~~	~~0,4~~
~~109~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Canis familiaris~~	~~NI~~	~~1~~	~~Cra, pal~~	~~-23.51~~	~~8.24~~	~~14.12~~	~~13.37~~	~~1.1~~	NA	~~111~~	~~16513~~	NA	NA	~~0,941~~	~~0,6~~
~~110~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Canis familiaris~~	~~NI~~	~~1~~	~~Costae~~	~~-20.47~~	~~12.61~~	~~4.305~~	~~26.21~~	~~7.09~~	NA	~~111~~	~~31525~~	NA	NA	~~0,84~~	~~0,6~~
~~111~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Bos primigenius~~	~~THE~~	~~1~~	~~Vert~~	~~-22.77~~	~~6.38~~	~~4.188~~	~~13.68~~	~~3.8~~	NA	~~111~~	~~21711~~	NA	NA	~~0,845~~	~~1,6~~
~~112~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Bos primigenius~~	~~THE~~	~~1~~	~~Costae~~	~~-22.62~~	~~6.53~~	~~3.71~~	~~14.84~~	~~4.66~~	NA	~~111~~	~~21711~~	NA	NA	~~0,968~~	~~0,8~~
113	Sunnansund	F	EM	Bos primigenius	THE	1	Hum	-18.58	6.36	3.523	17.85	5.9	NA	111	3713	NA	NA	0,77	0,9
~~114~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Bos primigenius~~	~~THE~~	~~1~~	~~Vert~~	~~-22.83~~	~~6.29~~	~~4.06~~	~~11.94~~	~~3.42~~	NA	~~111~~	~~3732~~	NA	NA	~~0,909~~	~~0,8~~
115	Sunnansund	F	EM	Bos primigenius	THE	1	Axis	-22.09	6.01	3.523	8.28	2.73	NA	111	26783	NA	NA	0,968	0,6
~~116~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Cervus elaphus~~	~~THE~~	~~1~~	~~Rad~~	~~-22.67~~	~~4.14~~	~~5.355~~	~~14.34~~	~~3.11~~	NA	~~111~~	~~28794~~	NA	NA	~~0,653~~	~~0,6~~
117	Sunnansund	F	EM	Cervus elaphus	THE	1	Ph 1	-22.46	4.5	3.43	16.01	5.44	NA	111	14981	NA	NA	0,733	0,8
118	Sunnansund	F	EM	Cervus elaphus	THE	1	Tib	-22.04	4.55	3.5	18.87	6.28	NA	111	16699	NA	NA	0,951	0,9
~~119~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Cervus elaphus~~	~~THE~~	~~1~~	~~Fem~~	~~-21.54~~	~~5.22~~	~~4.118~~	~~12.79~~	~~3.62~~	NA	~~111~~	~~23034~~	NA	NA	~~0,907~~	~~1,2~~
~~120~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Cervus elaphus~~	~~THE~~	~~1~~	~~Fem~~	~~-22.93~~	~~7.08~~	~~5.39~~	~~22.68~~	~~4.9~~	NA	~~111~~	~~20619~~	NA	NA	~~0,959~~	~~0,9~~
~~121~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Capreolus capreolus~~	~~THE~~	~~1~~	~~Hum~~	~~-22.19~~	~~6.79~~	~~4.678~~	~~16.3~~	~~4.05~~	NA	~~111~~	~~16053~~	NA	NA	~~0,835~~	~~0,9~~
122	Sunnansund	F	EM	Capreolus capreolus	THE	1	Rad	-21.4	6.94	3.231	34.8	12.51	NA	111	14957	NA	NA	1,033	0,6
~~123~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Capreolus capreolus~~	~~THE~~	~~1~~	~~Fem~~	~~-23.09~~	~~3.71~~	~~3.756~~	~~7.36~~	~~2.28~~	NA	~~111~~	~~16945~~	NA	NA	~~0,761~~	~~0,7~~
~~124~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Capreolus capreolus~~	~~THE~~	~~1~~	~~Rad~~	~~-23.01~~	~~4.42~~	~~4.083~~	~~28.82~~	~~8.21~~	NA	~~111~~	~~20632~~	NA	NA	~~0,808~~	~~0,7~~
~~125~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Capreolus capreolus~~	~~THE~~	~~1~~	~~Tib~~	~~-22.58~~	~~4.53~~	~~4.713~~	~~15.86~~	~~3.92~~	NA	~~111~~	~~16945~~	NA	NA	~~0,731~~	~~0,6~~
126	Sunnansund	F	EM	Alces alces	THE	1	Fem	-22.15	2.88	3.301	11.18	3.95	NA	111	21896	NA	NA	0,937	1,1
~~127~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Castor fiber~~	~~THE~~	~~1~~	~~Mand~~	~~-22.14~~	~~5.35~~	~~3.873~~	~~22.55~~	~~6.78~~	NA	~~111~~	~~15714~~	NA	NA	~~0,931~~	~~1,1~~
~~128~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Castor fiber~~	~~THE~~	~~1~~	~~Mand~~	~~-24.65~~	~~5.28~~	~~8.855~~	~~17.07~~	~~2.24~~	NA	~~111~~	~~28738~~	NA	NA	~~0,795~~	~~0,9~~
129	Sunnansund	F	EM	Lutra lutra	NI	1	Mand	-17.74	11.94	3.336	33.51	11.69	NA	111	25318	NA	NA	0,94	0,4
~~130~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Lutra lutra~~	~~NI~~	~~1~~	~~Hum~~	~~-22.16~~	~~12.06~~	~~5.95~~	~~15.69~~	~~3.07~~	NA	~~111~~	~~16724~~	NA	NA	~~0,638~~	~~0,8~~
~~131~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Sus scrofa~~	~~TOM~~	~~1~~	~~Tib~~	~~-22.01~~	~~5.76~~	~~4.526~~	~~13.82~~	~~3.55~~	NA	~~111~~	~~14963~~	NA	NA	~~0,286~~	~~1,4~~
132	Sunnansund	F	EM	Sus scrofa	TOM	1	Scap	-21.9	6.48	3.581	13.76	4.47	NA	111	14960	NA	NA	0,818	0,7
~~133~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Sus scrofa~~	~~TOM~~	~~1~~	~~Scap~~	~~-21.75~~	~~4.77~~	~~4.538~~	~~19.3~~	~~4.95~~	NA	~~111~~	~~23034~~	NA	NA	~~0,926~~	~~1,1~~
~~134~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Sus scrofa~~	~~TOM~~	~~1~~	~~M.pod~~	~~-24.84~~	~~8.93~~	~~12.81~~	~~19.51~~	~~1.77~~	NA	~~111~~	~~24787~~	NA	NA	~~0,851~~	~~0,8~~
135	Sunnansund	F	EM	Sus scrofa	TOM	1	Mand	-21.71	7.05	3.36	21.12	7.3	NA	111	21896	NA	NA	0,842	0,8
~~136~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Homo sapiens~~		~~1~~	~~Cra~~	~~-21~~	~~12.93~~	~~5.075~~	~~17.14~~	~~3.93~~	NA	~~112~~	~~12316~~	NA	NA	~~0,855~~	~~1,3~~
~~137~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Homo sapiens~~		~~1~~	~~Cra~~	~~-22.97~~	~~5.92~~	~~19.08~~	~~10.71~~	~~0.65~~	NA	~~112~~	~~12992~~	NA	NA	~~0,788~~	~~0,6~~

~~138~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Homo sapiens~~		~~1~~	~~Cra~~	~~-22.01~~	~~2.74~~	~~28.32~~	~~13.43~~	~~0.55~~	NA	~~112~~	~~12992~~	NA	NA	~~0,724~~	~~1~~
139	Balltorp	M	EM	Vulpes vulpes	NI	1	as	-18.52	7.89	3.32	43.66	15.34	3,74%	782	786	251,1	9,4	1,069	0,7
~~140~~	~~Balltorp~~	~~M~~	~~EM~~	~~Scomber scombrus~~	~~MLF~~	~~2~~	~~Vert~~	~~-13.79~~	~~12.97~~	~~3.78~~	~~42.45~~	~~13.1~~	~~1,23%~~	~~1316~~	~~1320~~	113,6	1,4	~~0,939~~	~~0,2~~
~~141~~	~~Balltorp~~	~~M~~	~~EM~~	~~Scomber scombrus~~	~~MLF~~	~~1~~	~~Vert~~	-	-	-	-	-	1,66%	~~1204~~	~~1208~~	60,2	1	-	~~0,1~~
142	Balltorp	M	EM	Sus scrofa	TOM	1	Cp	-21.92	5.84	3.26	42.96	15.37	2,95%	1204	1208	251	7,4	1,061	2,5
~~143~~	~~Balltorp~~	~~M~~	~~EM~~	~~Scomber scombrus~~	~~MLF~~	~~1~~	~~Vert~~	~~-17.44~~	~~11.61~~	~~3.768~~	~~40.05~~	~~12.4~~	~~0,29%~~	~~1057~~	~~1061~~	35	0,1	~~0,417~~	~~0,1~~
144	Balltorp	M	EM	Sus scrofa	TOM	1	M.pod	-21.93	6.69	3.37	34.5	11.94	0,40%	1326	1330	250	1	0,294	1,7
145	Balltorp	M	EM	Cervus elaphus	THE	1	Costae	-21.97	3.38	3.461	36.36	12.25	0,64%	679	683	250,1	1,6	1,112	2,2
~~146~~	~~Balltorp~~	~~M~~	~~EM~~	~~Scomber scombrus~~	~~MLF~~	~~1~~	~~Vert~~	~~-16.68~~	~~12.63~~	~~4.002~~	~~41.9~~	~~12.21~~	~~1,94%~~	~~1199~~	~~1203~~	67	1,3	~~0,972~~	~~0,1~~
147	Balltorp	M	EM	Capreolus capreolus	THE	1	M.pod	-21.1	3.65	3.346	31.55	11	0,04%	1219	1223	249,9	0,1	0,191	0,7
148	Balltorp	M	EM	Lepus timidus	THE	1	Tib	-21.02	7.06	3.471	43.17	14.51	2,31%	1184	1188	250,7	5,8	1,088	0,7
149	Balltorp	M	EM	Sus scrofa	TOM	1	Tib	-21.85	6.12	3.279	41.32	14.7	2,36%	1240	1244	249,6	5,9	1,032	1,6
150	Balltorp	M	EM	Halichoerus grypus	MAM	1	Cra	-17.04	14.39	3.332	42.68	14.94	2,59%	750	755	250,7	6,5	1,046	0,8
151	Balltorp	M	EM	Cervus elaphus	THE	1	Costae	-21.79	6.29	3.338	42.92	14.99	2,84%	725	729	249,8	7,1	1,024	1,3
152	Balltorp	M	EM	Halichoerus grypus	MAM	1	fi	-13.18	18.71	3.34	43.29	15.11	2,83%	725	729	251	7,1	1,032	1
153	Balltorp	M	EM	Capreolus capreolus	THE	1	M.tars	-24.2	2.84	3.332	43.56	15.25	1,75%	782	786	250,8	4,4	1,029	1,2
~~154~~	~~Balltorp~~	~~M~~	~~EM~~	~~Scomber scombrus~~	~~MLF~~	~~1~~	~~Vert~~	~~-16.74~~	~~13.51~~	~~3.774~~	~~50.29~~	~~15.54~~	~~2,17%~~	~~1169~~	~~1173~~	50,7	1,1	~~0,507~~	~~0,1~~
155	Balltorp	M	EM	Cervus elaphus	THE	1	Cox	-21.6	4	3.438	38.62	13.1	0,52%	1107		249,1	1,3	0,947	1,6
156	Balltorp	M	EM	Vulpes vulpes	NI	1	Cox	-17.01	9.48	3.305	43.69	15.42	3,79%	1080	1084	203,4	7,7	0,97	0,5
157	Balltorp	M	EM	Halichoerus grypus	MAM	1	M.pod	-19.2	14.2	3.375	42.63	14.73	3,20%		1168	250	8	1,073	1,5
158	Almeö 96A	F	EM	Cervus elaphus	THE	1	Scap	-21.42	4.33	3.291	43.03	15.25	3,36%	F30	schakt1	250,2	8,4	1,022	1
159	Almeö 96A	F	EM	Vulpes vulpes (c.fam?)	NI	1	Fem	-23.49	10.23	3.44	43.02	14.58	5,40%	L. 9	sch1:39	250,1	13,5	0,97	0,5
~~160~~	~~Almeö 96 b~~	~~F~~	~~EM~~	~~Canis familiaris~~	~~NI~~	~~1~~	~~Hum~~	-	-	-	-	-	NA	~~hund 1~~	~~G57~~	250,4		-	~~1,3~~
161	Almeö 96A	F	EM	Perca fluviatilis	FMF	15	Squa	-27.55	8.91	3.234	42.2	15.22	4,45%	x60y0:2	x60y0:2	249,6	11,1	1,067	0,7
162	Almeö 96A	F	EM	Perca fluviatilis	FMF	1	preop	-27.43	9.82	3.306	42.83	15.11	5,09%	x60y0:2	nivå 6 nr 11	249,5	12,7	1,083	0,7
163	Almeö 96A	F	EM	Cervus elaphus	THE	1	Fem	-21.79	4.26	3.301	42.76	15.11	5,90%	y0:4-0:3	nr 13	250,8	14,8	1,028	0,9
~~164~~	~~Almeö 96A~~	~~F~~	~~EM~~	~~Capreolus capreolus~~	~~THE~~	~~1~~	~~Calc~~	~~-23.46~~	~~3.86~~	~~3.754~~	~~20.55~~	~~6.38~~	~~1,20%~~	~~0:3:7~~	~~nr12~~	250,1	3	~~1,004~~	~~1~~
165	Almeö 96A	F	EM	Cervus elaphus	THE	1	Tib	-21.01	4.06	3.385	44.26	15.25	4,08%	y0:2		250,2	10,2	0,996	1
166	Almeö 96A	F	EM	Esox lucius	PIK	1	Pala	-25.03	11.2	3.419	43.87	14.97	6,24%	y0:2:5	nr8	249,8	15,6	1,068	0,7
167	Almeö 96A	F	EM	Perca fluviatilis	FMF	1	artic	-26.28	10.68	3.401	43.4	14.88	6,58%	Y0:3:6	nr6	247,8	16,3	1,045	0,5
168	Almeö 96A	F	EM	Esox lucius	PIK	1	Clei	-25.79	9.74	3.423	42.26	14.4	4,08%	Y0.4	nr16	250,1	10,2	0,977	0,5
169	Almeö 96A	F	EM	Capreolus capreolus	THE	1	M.tars	-21.86	2.98	3.422	44.08	15.02	4,15%	Y0.4:10		250,5	10,4	0,986	1,2
170	Almeö 96 b	F	EM	Canis familiaris	NI	1	Fem	-19.58	9.23	3.4	43.93	15.06	5,83%	nr 208:6	hund 3	250,4	14,6	1,03	1
171	Almeö 96 b	F	EM	Castor fiber	THE	1	Mand	-22.28	4.14	3.619	39.72	12.8	0,32%	nr 207		250,7	0,8	0,766	0,8
172	Almeö 96 b	F	EM	Esox lucius	PIK	1	Denta	-22.27	8.02	3.517	43.14	14.3	1,44%	nr89		250,5	3,6	1,053	1,1
173	Almeö 96 b	F	EM	Castor fiber	THE	1	Dens	-22.32	4.7	3.495	36.21	12.08	1,26%	nr 113		254,2	3,2	1,097	0,8
174	Almeö 96 b	F	EM	Bos primigenius	THE	1	M.tars	-21.27	2.85	3.298	42.51	15.04	4,21%	248		256,8	10,8	0,967	1
175	Almeö 96 b	F	EM	Alces alces	THE	1	Tib	-19.5	5.59	3.294	44.16	15.63	5,38%	nr 229		251	13,5	0,996	0,8

176	Almeö 96 b	F	EM	Sus scrofa	TOM	1	M.pod	-22.35	6.19	3.505	42.42	14.12	0,60%	nr 286		250,5	1,5	0,973	1,1
177	Almeö 96 b	F	EM	Esox lucius	PIK	1		-23.1	8.13	3.661	40.82	13	0,32%	nr1a		251,7	0,8	0,538	0,6
~~178~~	~~hästhagen 97b~~	~~F~~	~~EM~~	~~Canis familiaris~~	~~NI~~	~~1~~	~~Hum~~	-	-	-	-	-	NA	~~nr 5:1~~	~~F155~~	165,4		-	~~0,8~~
179	Almeö 96 b	F	EM	Sus scrofa	TOM	1	Hum	-22.15	5.8	3.574	42.54	13.88	1,16%	nr61		250,8	2,9	0,971	1,2
180	Almeö 96 b	F	EM	Esox lucius	PIK	1	Denta	-23.92	8.73	3.477	42.3	14.19	1,31%	nr175		251,3	3,3	1,056	0,5
181	Almeö 96 b	F	EM	Perca fluviatilis	FMF	4	preop, supclei	-24.33	7.01	3.476	42.76	14.35	1,04%	nr429		250,1	2,6	0,963	0,5
182	Almeö 96 b	F	EM	Sus scrofa	TOM	1	Mand	-22.26	5.71	3.462	45.12	15.2	6,08%	nr422:5		251,5	15,3	1,022	1,7
183	Almeö 96 b	F	EM	Alces alces	THE	1	M.pod	-23.03	2.01	3.577	41.56	13.55	0,72%	nr10		251	1,8	0,972	1,7
184	Almeö 96 b	F	EM	Esox lucius	PIK	1	Art	-24.73	8.08	3.47	42.48	14.28	1,28%	nr429		250,3	3,2	1,077	0,6
~~185~~	~~Almeö 96 b~~	~~F~~	~~EM~~	~~Castor fiber~~	~~THE~~	~~1~~	~~Cra~~	-	-	-	-	-	NA	~~nr429~~		250,3		-	~~0,7~~
~~186~~	~~Almeö 96 b~~	~~F~~	~~EM~~	~~Bos primigenius~~	~~THE~~	~~1~~	~~M.tars~~	~~-21.52~~	~~2.39~~	~~3.766~~	~~42.89~~	~~13.28~~	~~0,20%~~	~~nr18~~		250,5	0,5	~~0,466~~	~~1,1~~
~~187~~	~~Almeö 96 b~~	~~F~~	~~EM~~	~~Esox lucius~~	~~PIK~~	~~1~~	~~dent~~	~~-22.76~~	~~8.62~~	~~3.999~~	~~38.38~~	~~11.19~~	~~0,32%~~	~~nr415~~		250,2	0,8	~~0,643~~	~~0,8~~
~~188~~	~~Almeö 96 b~~	~~F~~	~~EM~~	~~Castor fiber~~	~~THE~~	~~1~~	~~Mand~~	~~-22.3~~	~~3.69~~	~~3.758~~	~~43.02~~	~~13.35~~	~~0,24%~~	~~nr214~~		250,7	0,6	~~0,45~~	~~0,9~~
189	Almeö 96 b	F	EM	Alces alces	THE	1	Ph1	-22.1	1.89	3.431	44.21	15.03	5,99%	nr236		251,9	15,1	1,004	1
190	Segebro	M	MM	Cervus elaphus	THE	1	Ph1	-22.43	3.82	3.191	43.01	15.72	5,13%	sch2	ruta g-h	251,3	12,9	0,998	0,5
191	Segebro	M	MM	Sus scrofa	TOM	1	Tib	-21.15	5.12	3.225	43.35	15.68	4,72%	sch2	ruta g-h	250	11,8	0,992	0,6
192	Segebro	M	MM	Capreolus capreolus	THE	1	Hum	-23.48	3.79	3.351	43.38	15.1	3,58%	sch2	ruta g-h	251,4	9	0,986	0,6
193	Segebro	M	MM	Sus scrofa	TOM	1	Ul	-21.04	6.12	3.252	43.08	15.45	5,39%	sch2	ruta f	250,3	13,5	0,989	0,4
194	Segebro	M	MM	Cervus elaphus	THE	1	Mand	-22.79	4.67	3.291	43.05	15.26	3,75%	sch2	ruta e	251	9,4	0,96	0,7
195	Segebro	M	MM	Halichoerus grypus	MAM	1	Cox	-16.7	13.12	3.318	42.14	14.81	2,67%	sch2	ruta e	251,3	6,7	0,984	0,5
~~196~~	~~Segebro~~	~~M~~	~~MM~~	~~Gadus morhua~~	~~MHF~~	~~1~~	~~Vert~~	~~-15.18~~	~~12~~	~~3.779~~	~~21.77~~	~~6.72~~	~~0,96%~~	~~sch2~~	~~rb~~	251,2	2,4	~~1,063~~	~~0,3~~
197	Segebro	M	MM	Halichoerus grypus	MAM	1	Tib	-14.29	13.2	3.205	42.77	15.56	4,67%	sch2	rA	250,7	11,7	1,056	0,9
198	Segebro	M	MM	Alces alces	THE	1	Fem	-20.93	4.94	3.281	44.68	15.88	4,14%	sch2	rA	251,1	10,4	0,997	0,6
199	Segebro	M	MM	Halichoerus grypus	MAM	1	Tib	-17.13	12.92	3.204	41.23	15.01	6,52%	sch2	rb	251,4	16,4	0,979	0,7
200	Segebro	M	MM	Ursus arctos	TOM	1	Hum	-20.75	4.74	3.246	44.85	16.12	5,78%	sch2	rb	250,7	14,5	1,014	0,9
201	Segebro	M	MM	Gadus morhua	MHF	1	Vert	-13.63	13.64	3.326	42.43	14.87	1,67%	sch2	rf	251,2	4,2	0,977	0,4
~~202~~	~~Ageröd I~~	~~F~~	~~EM~~	~~Canis familiaris~~	~~NI~~	~~1~~	~~Cra~~	~~-22.64~~	~~10.83~~	~~3.74~~	~~43.41~~	~~13.53~~	~~1,75%~~		~~x-2y27~~	250,8	4,4	~~1,023~~	~~0,5~~
203	Ageröd I:C	F	EM	Ursus arctos	TOM	1	Rad	-20.63	3.47	3.362	43.4	15.05	5,27%	I:C	x0y-1	250,6	13,2	0,987	0,5
204	Ageröd I:e	F	EM	Halichoerus grypus	FAM	1	Cox	-19.78	12	3.475	43.87	14.72	5,84%	I:E	x0y58	249,9	14,6	0,962	0,4
205	Ageröd I:A	F	EM	Phocidae	FAM	1	Costae	-19.81	11.85	3.551	44.4	14.58	3,66%	IA	x1y27	207,9	7,6	0,969	0,3
206	Ageröd I:A	F	EM	Sus scrofa	TOM	1	Mand	-21.86	4.16	3.626	44.23	14.23	3,54%	kulturlagret	x1y26	251,3	8,9	1,09	0,4
207	Ageröd I:C	F	EM	Cervus elaphus	THE	1	Tib	-23.53	2.94	3.543	43.79	14.41	3,96%	vita lagret	x-2y51	250,3	9,9	0,993	0,4
~~208~~	~~Ageröd I:A~~	~~F~~	~~EM~~	~~Capreolus capreolus~~	~~THE~~	~~1~~	~~Cox~~	~~-23.38~~	~~4.03~~	~~3.826~~	~~43.77~~	~~13.34~~	~~3,63%~~	~~vita lagret~~	~~x-2y49~~	251	9,1	~~1,077~~	~~0,5~~
~~209~~	~~Ageröd I:A~~	~~F~~	~~EM~~	~~Bos primigenius~~	~~THE~~	~~1~~	~~Vert~~	-	-	-	-	-	NA	~~kulturlagret~~	~~x-10y26~~	164,2		-	~~0,5~~
~~210~~	~~Ageröd I~~	~~F~~	~~EM~~	~~Alces alces~~	~~THE~~	~~1~~	~~Hum~~	~~-22.69~~	~~3.26~~	~~3.718~~	~~44.36~~	~~13.92~~	~~0,08%~~	~~kulturlagret~~		254,2	0,2	~~0,966~~	~~0,6~~
~~211~~	~~Bökeberg~~	~~F~~	~~LM~~	~~Esox lucius~~	~~PIK~~	~~1~~	~~Vert~~	~~-26.3~~	~~10.01~~	~~8.274~~	~~37.73~~	~~5.31~~	~~0,48%~~		~~2964~~	250,1	1,2	~~0,551~~	~~1,4~~
~~212~~	~~Bökeberg~~	~~F~~	~~LM~~	~~Esox lucius~~	~~PIK~~	~~1~~	~~Vert~~	~~-27.37~~	~~1.24~~	~~18.23~~	~~38.19~~	~~2.44~~	~~0,32%~~			251,7	0,8	~~0,437~~	~~1,2~~
~~213~~	~~Bökeberg~~	~~F~~	~~LM~~	~~Esox lucius~~	~~PIK~~	~~1~~	~~Art~~	-	-	-	-	-	NA			250,1		-	~~1,4~~

~~214~~	~~Bökeberg~~	~~F~~	~~LM~~	~~Cervus elaphus~~	~~THE~~	~~1~~	~~NA~~	~~-25.01~~	~~3.29~~	~~6.546~~	~~36.94~~	~~6.58~~	~~0,64%~~	NA	NA	250	1,6	~~0,975~~	~~1,7~~
215	Bökeberg	F	LM	Alces alces	THE	1	NA	-22.9	3.38	3.411	43.62	14.91	5,34%	NA	NA	251	13,4	1,024	1,5
~~216~~	~~Bökeberg~~	~~F~~	~~LM~~	~~Alces alces~~	~~THE~~	~~1~~	~~NA~~	~~-23.87~~	~~2.34~~	~~4.15~~	~~39.53~~	~~11.11~~	~~0,20%~~	NA	NA	250,4	0,5	~~0,36~~	~~0,9~~
~~217~~	~~Bökeberg~~	~~F~~	~~LM~~	~~Sus scrofa~~	~~TOM~~	~~1~~	~~NA~~	~~-23.62~~	~~1.13~~	~~5.043~~	~~38.27~~	~~8.85~~	~~0,04%~~	NA	NA	251,5	0,1	~~0,093~~	~~0,7~~
218	Bökeberg	F	LM	Sus scrofa	TOM	1	NA	-21.26	4.5	3.283	43.71	15.53	4,85%	NA	NA	251,4	12,2	1,066	0,6
~~219~~	~~Bökeberg~~	~~F~~	~~LM~~	~~Cervus elaphus~~	~~THE~~	~~1~~	~~Ph1~~	NA	NA	NA	NA	NA	NA	NA	NA	250		NA	~~1,6~~
~~220~~	~~Bökeberg~~	~~F~~	~~LM~~	~~Capreolus capreolus~~	~~THE~~	~~1~~	~~cornu~~	NA	NA	NA	NA	NA	NA	NA	NA	250		NA	~~1,1~~
~~221~~	~~Bökeberg~~	~~F~~	~~LM~~	~~Capreolus capreolus~~	~~THE~~	~~1~~	~~NA~~	~~-21.43~~	~~2.49~~	~~4.646~~	~~51.55~~	~~12.94~~	~~0,60%~~	NA	NA	250,1	1,5	~~0,215~~	~~0,4~~
~~222~~	~~Bökeberg~~	~~F~~	~~LM~~	~~Esox lucius~~	~~PIK~~	~~1~~	~~Pal~~	~~-27.08~~	~~-1.34~~	~~17.367~~	~~11.14~~	~~0.74~~	~~0,36%~~			250,1	0,9	~~1,048~~	~~1,1~~
~~223~~	~~Segebro~~	~~M~~	~~MM~~	~~Esox lucius~~	~~PIK~~	~~1~~	~~P.sph~~	~~-18.6~~	~~9.62~~	~~3.983~~	~~41.57~~	~~12.17~~	~~1,55%~~		~~114:17~~	251,3	3,9	~~0,998~~	~~1~~
~~224~~	~~Segebro~~	~~M~~	~~MM~~	~~Gadus morhua~~	~~MHF~~	~~1~~	~~Vert~~	~~-15.56~~	~~14.62~~	~~4.027~~	~~37.99~~	~~11~~	~~0,40%~~		~~115:18~~	249,8	1	~~0,827~~	~~1,3~~
225	Segebro	M	MM	Cervus elaphus	THE	1	NA	-22.81	3.61	3.536	43.48	14.34	1,91%	NA	NA	251,5	4,8	0,965	1,5
226	Gisslause	F	EM	Pusa hispida	FAM	1	NA	-20.95	11.14	3.688	41.92	13.26	0,08%	NA	NA	250	0,2	0,319	0,5
227	Gisslause	F	EM	Pusa hispida	FAM	1	NA	-20.46	12.41	3.564	41.1	13.45	0,68%	NA	NA	250,2	1,7	1,058	1,2
228	Gisslause	F	EM	Pusa hispida	FAM	1	NA	-19.82	9.94	3.431	43.26	14.71	0,67%	NA	NA	253,4	1,7	1,035	1,1
229	Gisslause	F	EM	Pusa hispida	FAM	1	M.pod	-20.38	12.44	3.556	42.1	13.81	0,43%	NA	NA	255,3	1,1	0,66	0,6
~~230~~	~~Gisslause~~	~~F~~	~~EM~~	~~Esox lucius~~	~~PIK~~	~~2~~	~~P.sph, Denta~~	-	-	-	-	-	NA	~~100/201~~	~~2b, 1d~~	250,6		-	~~0,3~~
~~231~~	~~Gisslause~~	~~F~~	~~EM~~	~~Cyprinidae~~	~~CYP~~	~~5~~	~~4Phar, 1Vert1~~	-	-	-	-	-	NA			251,6		-	~~0,4~~
~~232~~	~~Malmö C~~	~~F~~	~~MM~~	~~Abramis brama~~	~~CYP~~	~~1~~							NA	~~MK282:13~~	~~F101126~~	223			~~0,5~~
233	Malmö C	F	MM	Esox lucius	PIK	1	Quad	-15.3	9.68	3.385	34.82	12	0,87%	MK282:12	F101125	252,2	2,2	1,008	0,6
234	Malmö C	F	MM	Abramis brama	CYP	5	1 Oper, 4 Vert	-14.17	5.44	3.167	40.53	14.93	1,68%	MK282:20	F102052	225,7	3,8	1,04	0,4
235	Malmö C	F	MM	Perca fluviatilis	FMF	7	Vert, basocc,	-14.52	6.25	3.557	43.58	14.29	2,02%	MK282:16	F101647	89,3	1,8	0,977	0,2
236	Malmö C	F	MM	Esox lucius	PIK	2	Vert	-15.19	9.74	3.35	41.02	14.28	1,27%	MK282:15	F101646	251,5	3,2	1,067	0,6
237	Malmö C	F	MM	Anguilla anguilla	FCA	7	cleit, Vert,dent	-11.8	7.23	3.109	36.39	13.65	1,51%	MK282:21	F102134	251,8	3,8	1,004	0,3
238	Malmö C	F	MM	Anguilla anguilla	FCA	3	dent, art, cleit	-13.25	6.89	3.204	42.65	15.52	2,07%	MK282:19	F102051	251,3	5,2	0,995	0,4
239	Malmö C	F	MM	Abramis brama	CYP	11	preop, 10 Vert	-16.06	3.08	3.453	43.32	14.63	2,53%	MK 282:22	F102190	79	2	0,948	0,2
~~240~~	~~Ageröd I:HC~~	~~F~~	~~EM~~	~~Homo sapiens~~		~~1~~	~~nav~~	~~-21.14~~	~~10.76~~	~~3.763~~	~~43.81~~	~~13.58~~	~~2,85%~~	~~vita lagret~~	~~x-2y49~~	161,2	4,6	~~0,975~~	~~0,2~~
241	Ageröd IA	F	EM	Homo sapiens		1	Fem juv.	-18.8	13.2	3.44	44.35	15.04	3,78%	K.L.	x-9y30	251,3	9,5	1	0,4
~~242~~	~~Ageröd IA~~	~~F~~	~~EM~~	~~Homo sapiens~~		~~1~~	~~Ulna~~	~~-21.35~~	~~12.05~~	~~3.79~~	~~42.78~~	~~13.16~~	~~1,04%~~	~~K.L.~~	~~x-10y26~~	230,8	2,4	~~1,06~~	~~0,3~~
~~243~~	~~Ageröd I:HC~~	~~F~~	~~EM~~	~~Homo sapiens~~		~~1~~	~~Rad~~	~~-23.17~~	~~10.25~~	~~5.422~~	~~49.97~~	~~10.75~~	~~3,52%~~			249,8	8,8	~~1,014~~	~~0,4~~
244	Ageröd I	F	EM	Homo sapiens		1	Fem	-20.23	10.54	3.282	42.15	14.98	3,75%		36895 19	250,9	9,4	1,03	0,6
245	Ageröd I:HC	F	EM	Homo sapiens		1	Hum juv.	-18.61	13.23	3.336	39.77	13.9	6,78%	vita lagret	x0y51	249,1	16,9	1,088	0,4
~~246~~	~~Tågerup 1:1~~	~~M~~	~~MM~~	~~Esox lucius~~	~~PIK~~	~~1~~	~~Denta~~	-	-	-	-	-	NA	~~l.8~~	~~r2427f22220~~	250,4		-	~~0,4~~
~~247~~	~~Tågerup~~	~~M~~	~~MM~~	~~Esox lucius~~	~~PIK~~	~~1~~	quad	-	-	-	-	-	NA		~~fnr18083~~	248,3		-	~~0,4~~
~~248~~	~~Tågerup 1:1~~	~~M~~	~~MM~~	~~Perca fluviatilis~~	~~FMF~~	~~6~~	~~4 Vert. 2 Spin~~	~~-25.46~~	~~-11.1~~	~~7.761~~	~~5.62~~	~~0.84~~	~~0,12%~~	~~L.8~~	~~R2374~~	249,7	0,3	~~0,267~~	~~0,39~~
~~249~~	~~Tågerup 1:1~~	~~M~~	~~MM~~	~~Cyprinidae~~	~~CYP~~	~~7~~	~~Vert,Phardens~~						NA	~~L.8~~	~~R2064~~	251			~~0,39~~
250	Tågerup 1:1	M	MM	Perca fluviatilis	FMF	1	Oper	-10.98	11.16	3.311	39.63	13.96	1,40%	L.6	48621, f7885	250,5	3,5	0,994	0,8
~~251~~	~~Tågerup 1:1~~	~~M~~	~~MM~~	~~Esox lucius~~	~~PIK~~	~~1~~	~~Vert1~~						NA	~~L.8~~	~~R2369f18307~~	250,4			~~0,48~~

~~252~~	~~Tågerup 1:1~~	~~M~~	~~MM~~	~~Homo sapiens~~		~~1~~	~~Cra, temp~~	-	-	-	-	-	NA	~~Grav 4~~	~~A6504 (6438)~~	249,7		-	~~0,34~~
253	Skateholm II	M	LM	Esox lucius	PIK	1	Vert	-18.65	7.28	3.68	39.07	12.38	0,24%		x200y213	251,5	0,6	0,446	0,8
~~254~~	~~Skateholm II~~	~~M~~	~~LM~~	~~Cyprinidae~~	~~CYP~~	~~8~~	~~Vert~~						NA		~~x200y225~~	251,2			~~0,6~~
~~255~~	~~Skateholm II~~	~~M~~	~~LM~~	~~Esox lucius~~	~~PIK~~	~~5~~	~~Vert~~	-	-	-	-	-	NA		~~x199y221~~	251,1		-	~~0,48~~
~~256~~	~~Skateholm II~~	~~M~~	~~LM~~	~~Perca fluviatilis~~	~~FMF~~	~~5~~	~~Vert~~						NA		~~x199y221~~	250,6			~~0,44~~
~~257~~	~~Skateholm II~~	~~M~~	~~LM~~	~~Cyprinidae~~	~~CYP~~	~~3~~	~~Vert~~						NA		~~x199y221~~	250,3			~~0,43~~
~~258~~	~~Skateholm II~~	~~M~~	~~LM~~	~~Esox lucius~~	~~PIK~~	~~5~~	~~4 Vert, P.sph~~	~~-19.81~~	~~6.89~~	~~3.907~~	~~30.17~~	~~9~~	~~0,24%~~		~~x199y224~~	250,1	0,6	~~0,734~~	~~0,42~~
~~259~~	~~Skateholm II~~	~~M~~	~~LM~~	~~Perca fluviatilis~~	~~FMF~~	~~6~~	~~Vert~~						NA		~~x199y224~~	251,5			~~0,38~~
~~260~~	~~Skateholm II~~	~~M~~	~~LM~~	~~Cyprinidae~~	~~CYP~~	~~10~~	~~Vert~~	-	-	-	-	-	NA		~~x199y226~~	250,4		-	~~0,41~~
~~261~~	~~Skateholm II~~	~~M~~	~~LM~~	~~Perca fluviatilis~~	~~FMF~~	~~10~~	~~Vert~~						NA		~~x199y226~~	250,2			~~0,4~~
262	Skateholm II	M	LM	Esox lucius	PIK	1	Denta	-18.76	7.18	3.626	38.63	12.42	0,32%		x200y225	251	0,8	0,699	0,37
~~263~~	~~Skateholm II~~	~~M~~	~~LM~~	~~Silurus glanis~~	~~FMF~~	~~1~~	~~Vert~~	~~-23.02~~	~~8.99~~	~~4.031~~	~~22.18~~	~~6.41~~	NA		~~x199y221~~	250,3		~~0,201~~	~~0,31~~
~~264~~	~~Skateholm II~~	~~M~~	~~LM~~	~~Perca fluviatilis~~	~~FMF~~	~~11~~	~~Vert~~	-	-	-	-	-	NA		~~x199y220~~	249,5		-	~~0,42~~
~~265~~	~~Skateholm II~~	~~M~~	~~LM~~	~~Cyprinidae~~	~~CYP~~	~~12~~	~~Vert~~	-	-	-	-	-	NA		~~x199y220~~	249,7		-	~~0,41~~
~~266~~	~~Skateholm II~~	~~M~~	~~LM~~	~~Esox lucius~~	~~PIK~~	~~1~~	~~Pal~~						0,16%		~~x199y220~~	249,5	0,4	~~0~~	~~0,6~~
~~267~~	~~Skateholm II~~	~~M~~	~~LM~~	~~Anguilla anguilla~~	~~MCA~~	~~3~~	~~Vert~~						NA		~~x200200,25y220-220,25~~	143,5			~~0,16~~
~~268~~	~~Skateholm II~~	~~M~~	~~LM~~	~~Cyprinidae~~	~~CYP~~	~~3~~	~~Vert~~						NA		~~x200200,25y220-220,25~~	250,6		-	~~0,48~~
~~269~~	~~Gisslause~~	~~F~~	~~EM~~	~~Cyprinidae~~	~~CYP~~	~~6~~	~~4Vert, 2 Phar~~	~~-17.95~~	~~2.46~~	~~4.694~~	~~23.54~~	~~5.85~~	~~0,08%~~	~~101/199~~	~~2D~~	251,1	0,2	~~0,144~~	~~0,4~~
~~270~~	~~Gisslause~~	~~F~~	~~EM~~	~~Cyprinidae~~	~~CYP~~	~~9~~	~~5Phar. 4 Vert~~	~~-16.28~~	~~5.57~~	~~3.897~~	~~37.74~~	~~11.29~~	~~0,04%~~	~~101/199~~	~~1A; 3C~~	250,3	0,1	~~0,369~~	~~0,4~~
~~271~~	~~Gisslause~~	~~F~~	~~EM~~	~~Perca fluviatilis~~	~~FMF~~	~~9~~	~~Vert~~	~~-16.55~~	~~8.04~~	~~3.87~~	~~37.52~~	~~11.31~~	~~0,28%~~	~~101/199+103/199~~	~~2C, 3D, 2D,2B, 3D~~	212,5	0,6	~~0,44~~	~~0,2~~
~~272~~	~~Gisslause~~	~~F~~	~~EM~~	~~Cyprinidae~~	~~CYP~~	~~8~~	~~5Vert, 3 Phar~~	~~-17.26~~	~~6.16~~	~~4.458~~	~~36.14~~	~~9.45~~	~~0,04%~~	~~101/199~~	~~2C, 4A, 2D~~	251,6	0,1	~~0,259~~	~~0,3~~
~~273~~	~~Gisslause~~	~~F~~	~~EM~~	~~Esox lucius~~	~~PIK~~	~~5~~	~~3 Pal, 1 Denta~~	~~-18.6~~	~~8.81~~	~~4.183~~	~~35.64~~	~~9.93~~	~~0,04%~~	~~101/199~~	~~3B,2c~~	252	0,1	~~0,322~~	~~0,6~~
~~274~~	~~Gisslause~~	~~F~~	~~EM~~	~~Lota lota~~	~~FMF~~	~~6~~	~~Vert; 2+1+1+1+1~~	-	-	-	-	-	NA	~~101/199~~	~~3D,1C,2B,2C,4A~~	250,5		-	~~0,4~~
~~275~~	~~Gisslause~~	~~F~~	~~EM~~	~~Lota lota~~	~~FMF~~	~~4~~	~~3+1 Vert~~	~~-18.24~~	~~9.5~~	~~4.242~~	~~37.11~~	~~10.2~~	~~0,04%~~	~~103/199~~	~~2D, 6C~~	249,1	0,1	~~0,232~~	~~0,4~~
~~276~~	~~Gisslause~~	~~F~~	~~EM~~	~~Esox lucius~~	~~PIK~~	~~4~~	~~2 Denta, 2 Vert~~	~~-18.07~~	~~8.19~~	~~3.852~~	~~38.21~~	~~11.57~~	~~0,16%~~	~~103/199~~	~~6C,6D~~	250,9	0,4	~~0,189~~	~~0,4~~
277	Gisslause	F	EM	Cyprinidae	CYP	4	1Phar,3Vert,1Phar	-13.62	5.36	3.642	41.67	13.34	0,56%	103/199	4D, 3D, 5A	250,1	1,4	1,015	0,4
278	Gisslause	F	EM	Cyprinidae	CYP	1	1 Phar	-13.17	5.29	3.566	43.17	14.12	0,78%	103/199	5D	218	1,7	1,023	0,3
~~279~~	~~Gisslause~~	~~F~~	~~EM~~	~~Lota lota~~	~~FMF~~	~~2~~	~~Vert~~	~~-17.51~~	~~10.59~~	~~3.836~~	~~34.42~~	~~10.46~~	~~0,04%~~	~~103/199+100/201~~	~~5D+6B~~	251,6	0,1	~~0,26~~	~~0,5~~
~~280~~	~~Rönneholms mosse~~	~~F~~	~~MM~~	~~Esox lucius~~	~~PIK~~	~~2~~	~~Vert~~	~~-21.66~~	~~10.25~~	~~3.942~~	~~41.7~~	~~12.34~~	~~0,44%~~	~~wp 85~~	~~2008~~	251,3	1,1	~~0,858~~	~~0,35~~
~~281~~	~~Ringsjöholm~~	~~F~~	~~MM~~	~~Perca fluviatilis~~	~~FMF~~	~~7~~	~~Vert~~	-	-	-	-	-	NA	~~RH 3503:1~~	~~LP. 5983 x136 y96~~	250,5		-	~~0,33~~

~~282~~	~~Ringsjöholm~~	~~F~~	~~MM~~	~~Cyprinidae~~	~~CYP~~	~~8~~	~~3Vert 5 Phar dens~~	-	-	-	-	-	NA	~~RH 3503:1~~	~~LP:5984 (vert) + 5971 (pharyng.)~~	249,5		-	~~0,45~~
~~283~~	~~Ringsjöholm~~	~~F~~	~~MM~~	~~Esox lucius~~	~~PIK~~	~~2~~	~~Vert~~						NA	~~RH 3503:1~~	~~LP. 5982 x136 y96~~	251,9			~~0,57~~
~~284~~	~~Ringsjöholm~~	~~F~~	~~MM~~	~~Esox lucius~~	~~PIK~~	4	~~3Vert, 1 Pal~~						NA	~~RH 3503:1~~	~~Lp. 5978 x136 y96~~	251,5			~~0,51~~
~~285~~	~~Ringsjöholm~~	~~F~~	~~MM~~	~~Esox lucius~~	~~PIK~~	~~8~~	~~Vert~~						NA	~~RH 3503:1~~	~~Lp. 5982 x136 y96~~	250,5			~~0,38~~
~~286~~	~~Ringsjöholm~~	~~F~~	~~MM~~	~~Cyprinidae~~	~~CYP~~	~~2~~	~~Vert~~						NA	~~RH 5840~~	~~LP.318+314 x124 y104~~	251,8			~~0,31~~
~~287~~	~~Ringsjöholm~~	~~F~~	~~MM~~	~~Cyprinidae~~	~~CYP~~	~~8~~	~~2Vert 6 Phar~~						1,43%	~~RH: 5876,5869,5872,5869~~	~~385,498,505,504,509,501129130103,105,107~~	251	3,6	~~1,037~~	~~0,43~~
288	Tågerup	M	MM	Homo sapiens		1	Fem	-19.94	12.9	3.232	44.42	16.03	3,60%	R1526 L.4	fyndbr:11874	253	9,1	1,034	0,8
289	Skibevall	M	EM	Homo sapiens		1	Cra	-16.47	15.44	3.39	44.93	15.46	2,11%	zoomus 41	Kville	256,1	5,4	1,002	0,6
290	Malmö Hamn	F	EM	Homo sapiens		1	Fem	-17.08	9.48	3.215	44.77	16.24	5,30%			256,4	13,6	0,948	0,9
291	Huseby klev	M	EM	Lagenorhynchus alb	MAM	1	Vert	-13.47	15.7	3.426	43.25	14.72	1,97%	F14	djupa gropen	254,3	5	0,996	0,97
292	Huseby klev	M	EM	Lagenorhynchus alb	MAM	1	Vert	-12.66	15.75	3.248	44.22	15.88	2,19%	F6263	djupa gropen	250,8	5,5	0,98	0,88
293	Huseby klev	M	EM	Lagenorhynchus alb	MAM	1	Vert	-13.72	14.86	3.383	44.06	15.19	1,88%	F958	djupa gropen	250,4	4,7	0,997	0,72
294	Huseby klev	M	EM	Lagenorhynchus alb	MAM	1	Vert	-12.88	15.71	3.254	42.8	15.34	2,61%	F3097	djupa gropen	249,4	6,5	1,074	1,7
295	Huseby klev	M	EM	Cervus elaphus	THE	1	Ph2	-21.22	2.5	3.258	43.49	15.57	3,00%	F940	djupa gropen	253,1	7,6	1,032	0,61
296	Huseby klev	M	EM	Cervus elaphus	THE	1	axis	-21.4	2.44	3.426	43.62	14.85	2,86%	F954	djupa gropen	251,6	7,2	0,99	0,48
297	Huseby klev	M	EM	Phocoena phocoena	MAM	1	Vert	-13.93	15.54	3.303	44.33	15.65	2,95%	f856	djupa gropen	250,5	7,4	1,024	0,37
298	Huseby klev	M	EM	Phocoena phocoena	MAM	1	Vert	-13.49	15.9	3.263	42.7	15.26	2,74%	100	djupa gropen	251,9	6,9	1,01	0,42
~~299~~	~~Huseby klev~~	~~M~~	~~EM~~	~~Rangifer tarandus~~	~~THE~~	~~1~~	~~cornu~~	-	-	-	-	-	NA	~~3737~~	~~djupa gropen~~	251,3		-	~~0,61~~
300	Huseby klev	M	EM	Sus scrofa	TOM	1	Cra	-21.3	4.45	3.414	44.12	15.07	1,82%	7	djupa gropen	257,8	4,7	0,98	0,63
301	Huseby klev	M	EM	Sus scrofa	TOM	1	Scap	-21.72	1.76	3.501	37.37	12.45	0,24%	528	djupa gropen	254,3	0,6	0,102	1,48
302	Huseby klev	M	EM	Castor fiber	THE	1	Mand	-21.26	2.87	3.457	42.42	14.31	0,36%	102	djupa gropen	253,4	0,9	0,723	0,4
303	Huseby klev	M	EM	Vulpes vulpes	NI	1	Hum	-19.71	6.85	3.342	43.87	15.31	1,37%	30	djupa gropen	255,2	3,5	0,969	0,46
304	Huseby klev	M	EM	Lutra lutra	NI	1	Ulna	-9.96	15.63	3.225	44.61	16.14	2,99%	554	djupa gropen	254,1	7,6	0,99	0,39
305	Huseby klev	M	EM	Capreolus capreolus	THE	1	Rad	-21.89	3.62	3.588	43.35	14.09	0,23%	562	djupa gropen	255,8	0,6	0,6	0,43
306	Huseby klev	M	EM	Alces alces	THE	1	Ulna	-21.03	2.56	3.267	44.18	15.77	2,32%	944	djupa gropen	250,5	5,8	1,004	0,45
307	Huseby klev	M	EM	Phocidae	MAM	1	Tib	-14.22	16.85	3.447	37.19	12.58	0,12%	Lager 85	djupa gropen	253	0,3	0,14	0,44
~~308~~	~~Huseby klev~~	~~M~~	~~EM~~	~~Halichoerus grypus~~	~~MAM~~	~~1~~	~~Cra~~	~~-14.46~~	~~19.08~~	~~3.779~~	~~36.62~~	~~11.3~~	~~0,04%~~	~~537~~	~~djupa gropen~~	250,6	0,1	~~0,317~~	~~0,38~~
309	Huseby klev	M	EM	Halichoerus grypus	MAM	1	Rad	-13.12	18.96	3.468	44.62	15	3,48%	900	djupa gropen	249,9	8,7	1,005	0,89
310	Huseby klev	M	EM	Halichoerus grypus	MAM	1	Cra	-14.56	16.55	3.554	45.52	14.94	1,80%	553	djupa gropen	250,4	4,5	1,065	0,51
311	Huseby klev	M	EM	Halichoerus grypus	MAM	1	Scap	-11.95	18.01	3.336	44.85	15.68	3,63%	953	djupa gropen	250,6	9,1	0,99	0,41
~~312~~	~~Huseby klev~~	~~M~~	~~EM~~	~~Pinguinus impennis~~	~~NI~~	~~1~~	~~Hum~~	~~-15.6~~	~~19.21~~	~~4.045~~	~~42.88~~	~~12.36~~	~~0,04%~~	~~949~~	~~djupa gropen~~	251,7	0,1	~~0,42~~	~~0,6~~
~~313~~	~~Huseby klev~~	~~M~~	~~EM~~	~~Pinguinus impennis~~	~~NI~~	~~1~~	~~Hum~~	~~-15.96~~	~~17.87~~	~~4.136~~	~~47.85~~	~~13.49~~	~~0,48%~~	~~630~~	~~djupa gropen~~	250,9	1,2	~~1,022~~	~~0,48~~

314	Huseby klev	M	EM	Homo sapiens		1	Cra	-15.56	15.32	3.523	46.61	15.43	3,78%	92	djupa gropen	251,5	9,5	0,985	0,43
~~315~~	~~Huseby klev~~	~~M~~	~~EM~~	~~Gadus morhua~~	~~MHF~~	~~3~~	~~Vert~~	~~-21.14~~	~~11.39~~	~~7.923~~	~~32.75~~	~~4.82~~	~~0,24%~~	~~579~~	~~djupa gropen~~	248,8	0,6	~~0,402~~	~~0,43~~
316	Huseby klev	M	EM	Gadus morhua	MHF	1	Vert	-15.52	11.03	3.577	27.6	9	0,04%	26	djupa gropen	250,7	0,1	0,09	0,7
~~317~~	~~Huseby klev~~	~~M~~	~~EM~~	~~Squalus acanthias~~	~~MHF~~	~~2~~	~~piggar~~	~~-17.82~~	~~11.5~~	~~5.459~~	~~43.82~~	~~9.36~~	~~0,24%~~	~~lager 46~~	~~djupa gropen~~	250,8	0,6	~~0,461~~	~~0,36~~
318	Huseby klev	M	EM	Pleuronectes platessa	MLF	1	anale	-12.93	13.97	3.542	39.07	12.86	0,24%	6252	djupa gropen	250,6	0,6	0,574	0,54
~~319~~	~~Huseby klev~~	~~M~~	~~EM~~	~~Scomber scombrus~~	~~MLF~~	~~3~~	~~Vert~~	~~-16.91~~	~~11.22~~	~~3.733~~	~~42.34~~	~~13.23~~	~~1,24%~~	~~99.517.463~~	~~djupa gropen~~	250,3	3,1	~~0,983~~	~~0,33~~
320	Huseby klev	M	EM	Sus scrofa	TOM	1	pat	-21.2	3.78	3.275	43.96	15.66	2,92%	3070	tältet	250,4	7,3	0,987	0,33
321	Huseby klev	M	EM	Sus scrofa	TOM	1	atlas	-20.92	5.68	3.418	20.65	7.04	0,96%	127	tältet	249,9	2,4	1,058	0,43
322	Huseby klev	M	EM	Cervus elaphus	THE	1	Scap	-22	2.88	3.636	39.37	12.63	0,36%	431	tältet	250,6	0,9	0,873	0,56
323	Huseby klev	M	EM	Capreolus capreolus	THE	1	Tib	-22.6	2.66	3.405	44.27	15.16	1,12%	122	Tältet	250,7	2,8	0,947	0,66
324	Huseby klev	M	EM	Lagenorhynchus alb	MAM	1	Scap	-12.95	15.22	3.199	44.28	16.14	5,63%	3009	Tältet	238,1	13,4	0,994	0,27
~~325~~	~~Huseby klev~~	~~M~~	~~EM~~	~~Pinguinus impennis~~	~~NI~~	~~1~~	~~Hum~~	-	-	-	-	-	NA	~~493~~	~~Tältet~~	249,2		-	~~0,54~~
~~326~~	~~Huseby klev~~	~~M~~	~~EM~~	~~Gadus morhua~~	~~MHF~~	~~1~~	~~Vert~~	-	-	-	-	-	NA	~~L22~~	~~Tältet~~	249,9		-	~~0,83~~
~~327~~	~~Huseby klev~~	~~M~~	~~EM~~	~~Molva molva~~	~~MHF~~	~~1~~	~~Vert~~	~~-23.94~~	~~9.77~~	~~4.195~~	~~13.67~~	~~3.8~~	NA	~~127~~	~~Tältet~~	249,4		~~0,14~~	~~0,56~~
~~328~~	~~Huseby klev~~	~~M~~	~~EM~~	~~Clupea harengus~~	~~MLF~~	56	~~Vert~~						NA	~~124~~	~~Tältet~~	225			~~0,31~~
~~329~~	~~Huseby klev~~	~~M~~	~~EM~~	~~Gadus morhua~~	~~MHF~~	~~2~~	~~Vert~~	-	-	-	-	-	NA	~~124~~	~~Tältet~~	250		-	~~0,4~~
330	Huseby klev	M	EM	Squalus acanthias	MHF	13	Vert	-14.27	11.85	3.594	42.35	13.74	0,96%	128	Tältet	250,1	2,4	0,987	0,4
331	Huseby klev	M	EM	Molva molva	MHF	2	Vert	-13.36	11.99	3.47	29.94	10.06	NA	120	Tältet	250,3		0,401	0,45
~~332~~	~~Huseby klev~~	~~M~~	~~EM~~	~~Gadus morhua~~	~~MHF~~	~~1~~	~~Vert~~	-	-	-	-	-	0,36%	~~3683~~	~~hyddan~~	249	0,9	~~0~~	~~0,37~~
~~333~~	~~Huseby klev~~	~~M~~	~~EM~~	~~Gadus morhua~~	~~MHF~~	4	~~Vert~~	-	-	-	-	-	NA	~~3144~~	~~hyddan~~	249,9		-	~~0,38~~
~~334~~	~~Huseby klev~~	~~M~~	~~EM~~	~~Cervus elaphus~~	~~THE~~	~~1~~	~~M.tars~~	~~-21.88~~	~~3.34~~	~~3.724~~	~~43.88~~	~~13.74~~	~~0,28%~~	~~3439~~	~~hyddan~~	249,7	0,7	~~0,106~~	~~0,38~~
335	Huseby klev	M	EM	Phoca vitulina	MAM	1	Cra	-15.68	14.97	3.404	38.55	13.21	0,47%	3627	hyddan	254,3	1,2	0,324	0,57
~~336~~	~~Huseby klev~~	~~M~~	~~EM~~	~~Capreolus capreolus~~	~~THE~~	~~1~~	~~M.tars~~	-	-	-	-	-	NA	~~3101~~	~~hyddan~~	249,5		-	~~0,45~~
337	Huseby klev	M	EM	Sus scrofa	TOM	1	Mand	-21.18	3.7	3.369	37.8	13.09	0,84%	3115	hyddan	250,2	2,1	1,053	0,37
338	Huseby klev	M	EM	Sus scrofa	TOM	1	Dens	-21.78	4.66	3.355	43.43	15.1	0,60%	3448	hyddan	250	1,5	0,995	0,38
339	Huseby klev	M	EM	Pinguinus impennis	NI	1	Fem	-14.85	14.44	3.383	42.1	14.51	1,99%	3448	hyddan	251,5	5	0,961	0,4
340	Huseby klev	M	EM	Halichoerus grypus	MAM	1	Dens	-13.52	19.02	3.423	38.24	13.03	0,64%	589	hyddan	250,6	1,6	1,049	0,46
341	Sunnansund	F	EM	Lota lota	FMF	13	Vert	-17.19	9.05	3.634	34.81	11.17	0,40%	ferment	profil 1	252,1	1	0,495	0,42
342	Sunnansund	F	EM	Anguilla anguilla	FCA	23	Vert	-19.85	7.95	3.388	38.77	13.34	1,00%	ferment	profil 1	250,4	2,5	1,015	0,44
343	Sunnansund	F	EM	Perca fluviatilis	FMF	25	Vert	-17.19	8.26	3.441	42.26	14.32	0,68%	ferment	profil 1	250,2	1,7	0,968	0,52
~~344~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Esox lucius~~	~~PIK~~	4	~~Vert~~	~~-19.26~~	~~9.6~~	~~3.797~~	~~29.91~~	~~9.19~~	~~0,24%~~	~~ferment~~	~~profil 1~~	250,3	0,6	~~0,518~~	~~0,53~~
~~345~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Cyprinidae~~	~~CYP~~	~~37~~	~~Vert~~	~~-24.68~~	~~6.71~~	~~12.227~~	~~54.88~~	~~5.23~~	~~0,48%~~	~~ferment~~	~~profil 1~~	249,5	1,2	~~1,017~~	~~0,5~~
~~346~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Scardinius erythrophthalmus~~	~~CYP~~	~~1~~	~~Phar~~	~~-19.59~~	~~6.87~~	~~3.721~~	~~20.53~~	~~6.43~~	NA	~~ferment~~	~~profil 1~~	249,9		~~0,091~~	~~0,39~~
~~347~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Rutilus rutilus~~	~~CYP~~	~~1~~	~~Phar~~	~~-16.39~~	~~6.33~~	~~3.703~~	~~21.24~~	~~6.69~~	~~0,12%~~	~~ferment~~	~~profil 1~~	250,4	0,3	~~0,227~~	~~0,36~~
~~348~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Rutilus rutilus~~	~~CYP~~	~~5~~	~~Phar~~	~~-16.3~~	~~6.43~~	~~3.727~~	~~31.48~~	~~9.85~~	~~0,28%~~	~~ferment~~	~~profil 1~~	251,9	0,7	~~0,307~~	~~0,45~~
~~349~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Cervus elaphus~~	~~THE~~	~~1~~	~~Mand~~	-	-	-	-	-	0,16%	~~111~~	~~28785~~	250,8	0,4	~~0,017~~	~~0,82~~
350	Sunnansund	F	EM	Bos primigenius	THE	1	Vert	-22.09	5.58	3.506	43.41	14.44	1,79%	111	21711	251,2	4,5	0,984	1,41

~~351~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Pusa hispida~~	~~FAM~~	~~1~~	~~Scap~~	~~-20.35~~	~~12.36~~	~~3.743~~	~~33.67~~	~~10.49~~	~~0,56%~~	~~111~~	~~21714~~	250,7	1,4	~~0,669~~	~~0,77~~
352	Sunnansund	F	EM	Phocidae	FAM	1	Costae	-19.63	11.51	3.628	29.54	9.49	0,32%	111	21708	250,6	0,8	0,805	0,52
~~353~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Halichoerus grypus~~	~~FAM~~	~~1~~	~~Cra, bulla~~	~~-20.8~~	~~12.61~~	~~4.13~~	~~36.06~~	~~10.18~~	~~0,28%~~	~~111~~	~~18074~~	251,4	0,7	~~0,624~~	~~1,04~~
354	Sunnansund	F	EM	Sus scrofa	TOM	1	Tib	-21.99	6.52	3.596	35.45	11.5	0,28%	111	15914	251,6	0,7	0,22	0,56
~~355~~	~~Sunnansund~~	~~F~~	~~EM~~	~~Sus scrofa~~	~~TOM~~	~~1~~	~~Costae~~	-	-	-	-	-	0,04%	~~111~~	~~20619~~	250	0,1	~~0,074~~	~~0,78~~
~~356~~	~~Kongemose~~	~~F~~	~~MM~~	~~Esox lucius~~	~~PIK~~	~~1~~	~~Vert~~	~~-24.62~~	~~7.43~~	~~4.438~~	~~56.62~~	~~14.88~~	~~5,09%~~	~~37/33-2~~	~~P104/2015A~~	251,6	12,8	~~1,069~~	~~0,96~~
~~357~~	~~Kongemose~~	~~F~~	~~MM~~	~~Esox lucius~~	~~PIK~~	~~3~~	~~Vert~~						NA	~~37/14-2~~	~~P103/2015A~~	250,9		~~0,004~~	~~0,82~~
~~358~~	~~Svaerdborg~~	~~F~~	~~EM~~	~~Esox lucius~~	~~PIK~~	~~2~~	~~Denta~~	~~-26.05~~	~~-6.12~~	~~13.04~~	~~38.56~~	~~3.44~~	~~0,12%~~	~~LxIII G5~~	~~P127/2015A~~	250	0,3	~~0,115~~	~~0,79~~
~~359~~	~~Lundby II~~	~~F~~	~~EM~~	~~Esox lucius~~	~~PIK~~	~~4~~	~~Vert~~	~~-23.5~~	~~6.28~~	~~6.867~~	~~40.48~~	~~6.87~~	~~0,12%~~	~~F10~~	~~P105/2015A~~	250,4	0,3	~~0,292~~	~~0,97~~
~~360~~	~~Ulkestrup Lyng~~	~~F~~	~~EM~~	~~Esox lucius~~	~~PIK~~	~~3~~	~~Vert~~	~~-21.4~~	~~7.93~~	~~3.754~~	~~42.98~~	~~13.35~~	~~3,48%~~	~~23320-1~~	~~P130/2015A~~	250,3	8,7	~~0,983~~	~~0,85~~
361	Ulkestrup Lyng	F	EM	Perca fluviatilis	FMF	5	Cra	-23.17	7.98	3.578	43.48	14.17	4,90%	23320-2	P128/2015A	251	12,3	1,053	0,6
362	Ulkestrup Lyng	F	EM	Esox lucius	PIK	1	Vert	-22.2	8	3.546	43.61	14.34	7,71%	23305-2	P131/2015A	250,4	19,3	0,995	0,57
363	Ulkestrup Lyng	F	EM	Perca fluviatilis	FMF	1	Denta	-23.33	8.1	3.461	38.72	13.05	3,32%	23313-92	P129/2015A	229	7,6	0,983	0,26
~~364~~	~~Ulkestrup Lyng~~	~~F~~	~~EM~~	~~Tinca tinca~~	~~CYP~~	~~99~~	~~Cra~~	-	-	-	-	-	NA	~~23320-2~~	~~P132/2015A~~	251,7		-	~~0,8~~
~~365~~	~~Praestelyngen~~	~~F~~	~~N~~	~~Cyprinidae~~	~~CYP~~	~~7~~	~~Vert~~	~~-26.66~~	~~3.78~~	~~4.511~~	~~44.13~~	~~11.41~~	~~0,52%~~	~~384395; 3958;5612-152;11491-6;16425;24484-50~~	~~P18,119,120,121,122, 123~~	250,9	1,3	~~0,833~~	~~0,44~~
366	Praestelyngen	F	N	Esox lucius	PIK	1	Quad	-24.66	7.93	3.666	44.06	14.02	3,06%	12471	P126/2015AN	251,9	7,7	1,069	0,96
367	Praestelyngen	F	N	Esox lucius	PIK	1	Vert	-20.35	8.58	3.401	42.82	14.68	1,97%	2112-112	P124/2015AN	248,8	4,9	1,009	0,43
~~368~~	~~Praestelyngen~~	~~F~~	~~N~~	~~Perca fluviatilis~~	~~FMF~~	~~5~~	~~Vert~~	-	-	-	-	-	NA	~~10651;12419;1875742;19242;5615-184~~	~~P113,114,115,116,117~~			-	~~0,45~~
369	Muldbjerg	F	EM	Rutilus rutilus	CYP	99	Vert etc.	-25.9	4.39	3.344	43.7	15.24	3,18%	32935	P110/2015AN	248,1	7,9	1,008	0,62
~~370~~	~~Muldbjerg~~	~~F~~	~~EM~~	~~Rutilus rutilus~~	~~CYP~~	~~99~~	~~Vert etc.~~	~~-25.68~~	~~3.18~~	~~3.875~~	~~44.39~~	~~13.36~~	~~2,60%~~	~~50702~~	~~P111/2015AN~~	249,7	6,5	~~0,983~~	~~0,72~~
371	Muldbjerg	F	EM	Perca fluviatilis	FMF	99	Squa, Vert, Cra	-25.93	7.14	3.435	44.05	14.95	4,40%	37930	P107/2015AN	250,2	11	1,017	0,92
372	Muldbjerg	F	EM	Perca fluviatilis	FMF	99	Squa, Vert, Cra	-24.71	7.73	3.171	44.58	16.4	4,44%	37227	P106/2015AN	249,8	11,1	1,037	0,99
373	Muldbjerg	F	EM	Esox lucius	PIK	1	Vert	-25	8.11	3.637	43.65	14	2,72%	48244	P109/2015AN	250,3	6,8	1,035	0,61
374	Muldbjerg	F	EM	Esox lucius	PIK	1	Vert	-25.27	7.33	3.624	43.75	14.08	2,12%	62670	P108/2015AN	249,9	5,3	1,021	0,63
375	Gisslause	F	NEO	Homo sapiens	NI	1	Cra	-20.09	13.03	3.266	43.89	15.67	3,23%	18912	NR XXVII	250,4	8,1	0,991	0,45
376	Gisslause	F	NEO	Homo sapiens	NI	1	Fem	-20.06	13.05	3.376	44.78	15.47	3,55%	18912		250,4	8,9	1,038	0,45
377	Gisslause	F	NEO	Homo sapiens	NI	1	Cra, par	-20.08	13.2	3.246	43.47	15.62	3,41%	18912		249,5	8,5	1,077	0,27
378	Strå	F	MM	Pusa hispida	FAM	1	Dentes	-19.31	13.96	3.273	41.8	14.89	3,54%	22256	D2	251,1	8,9	0,977	0,35
379	Strå	F	MM	Pusa hispida	FAM	1	Ulna	-19	10.82	3.334	43.54	15.23	3,00%	21552	B9	249,9	7,5	1,074	0,54
380	Strå	F	MM	Pusa hispida	FAM	1	Fem	-19.27	12.28	3.422	43.77	14.91	2,04%	21552-B9	7406:59	250,5	5,1	1,041	0,48
381	Strå	F	MM	Halichoerus grypus	FAM	1	Hum	-19.07	12.1	3.389	44.13	15.19	2,92%	22256-D5	7406:144	249,7	7,3	0,955	0,61
382	Strå	F	MM	Pusa hispida	FAM	1	Hum	-19.13	10.23	3.355	44.5	15.47	2,67%	21552	littorinavallen	251,1	6,7	0,964	0,82

~~383~~	~~Strå~~	~~F~~	~~MM~~	~~Esox lucius~~	~~PIK~~	~~2~~	~~Vert~~	~~-15.71~~	~~7.38~~	~~4.369~~	~~32.56~~	~~8.69~~	~~0,07%~~	~~22256 D2~~	~~7406:147~~	134,9	0,1	~~0,334~~	~~0,14~~
384	stora förvar	F	EM	Homo sapiens		1	Tib	-17.58	12.13	3.281	43.49	15.46	4,41%	F11		102,1	4,5	1,009	0,11
385	stora förvar	F	EM	Homo sapiens		1	NA	-19.85	9.73	3.456	43.79	14.78	3,11%	F13		96,6	3	0,977	0,12
386	stora förvar	F	EM	Homo sapiens		1	NA	-17.81	10.88	3.426	44.63	15.19	2,46%	F12		117,8	2,9	0,96	0,12
~~387~~	~~Bökeberg~~	~~F~~	~~LM~~	~~Homo sapiens~~	~~NI~~	~~1~~	~~Cra~~	-	-	-	-	-	NA	~~x86,55~~ ~~y85,27~~ ~~z44,38~~	~~fnr:619~~	250,3		-	~~0,33~~
~~388~~	~~Bökeberg~~	~~F~~	~~LM~~	~~Homo sapiens~~	~~NI~~	~~1~~	~~Cra~~	-	-	-	-	-	NA	~~x86,31y85,~~	~~623~~	324,8		-	~~0,51~~
389	Stora förvar	F	EM-MM	Pusa hispida	FAM	1	Rad	-18.58	12.35	3.31	44.38	15.64	4,43%	14344 F12	G145 (308)	250,4	11,1	0,998	0,35
390	Stora förvar	F	EM-MM	Pusa hispida	FAM	1	Rad	-19.64	11.18	3.221	43.82	15.87	4,60%	14344 F12	G145 (308)	252,1	11,6	1,067	0,55
391	Stora förvar	F	EM-MM	Pusa hispida	FAM	1	Rad	-19.22	12.34	3.261	44.75	16.01	4,86%	14344 F12	G145 (308)	248,9	12,1	0,995	0,62
392	Stora förvar	F	EM-MM	Pusa hispida	FAM	1	Rad	-20.35	11.36	3.376	43.25	14.94	0,48%	14344 F13	G145 (166)	250,3	1,2	0,96	0,38
393	Stora förvar	F	EM-MM	Pusa hispida	FAM	1	Rad	-19.49	12.02	3.266	44.09	15.74	3,07%	14344 F13	G145 (166)	251,2	7,7	0,992	0,64
394	Stora förvar	F	EM-MM	Pusa hispida	FAM	1	Rad	-19.34	10.8	3.264	44.36	15.85	4,80%	14344 F13	G145 (166)	249,8	12	0,946	0,43
395	Stora förvar	F	EM-MM	Pusa hispida	FAM	1	Rad	-19.29	11.94	3.178	43.52	15.97	3,83%	14344 F10	G145 (168)	250,5	9,6	1,039	0,35
396	Stora förvar	F	EM-MM	Pusa hispida	FAM	1	Rad	-19.8	12.25	3.182	44.24	16.21	3,67%	14344 F10	G145 (168)	250,4	9,2	1,004	0,38
397	Stora förvar	F	EM-MM	Pusa hispida	FAM	1	Rad	-19.47	11.72	3.185	43.36	15.88	4,00%	14344 F10	G145 (168)	250,1	10	1,015	0,53
398	Stora förvar	F	EM-MM	Halichoerus grypus	FAM	1	Fem	-18.85	12.77	3.292	44.6	15.8	5,00%	14344 F12	G145 (545)	250	12,5	0,983	0,44
399	Stora förvar	F	EM-MM	Halichoerus grypus	FAM	1	Fem	-19.32	11.82	3.229	43.59	15.74	4,88%	14344 F12	G145 (545)	211,1	10,3	0,988	0,26
400	Stora förvar	F	EM-MM	Pusa hispida	FAM	1	Rad	-19.23	11.72	3.286	44.74	15.88	4,20%	14344 F9	G129	240,7	10,1	1,094	0,29
401	Stora förvar	F	EM-MM	Pusa hispida	FAM	1	Rad	-19.1	11.25	3.189	43.2	15.8	4,24%	14344 F9	G129	252,4	10,7	1,03	0,46
402	Stora förvar	F	EM-MM	Pusa hispida	FAM	1	Rad	-19.55	10.83	3.219	43.82	15.88	3,72%	14344 F9	G129	250,1	9,3	1	0,36
403	Skanör	M	LM	Homo sapiens	NI	1	Hum	-13.68	15.53	3.273	43.69	15.57	4,29%	n.reveln	6305±40	218,9	9,4	1,059	0,26
404	Måkläppen	M	MM	Homo sapiens		1	Fem	-15.8	13.95	3.317	42.73	15.03	4,35%		dat 7150bp	218,3	9,5	1,056	0,34
405	Ö.Vannborga	F	EM	Homo sapiens		1	Fem	-17.46	11.5	3.307	45.41	16.02	4,23%	A1662	Öland	250,3	10,6	0,98	0,29
~~406~~	~~Bua Västergård~~	~~M~~	~~MM~~	~~Molva molva~~	~~MHF~~	~~1~~	~~artikulare~~	~~-24.98~~	-	-	~~1.75~~	-	NA		~~GAM:84424:559:1~~			~~0,293~~	~~0,7~~
~~407~~	~~Bua Västergård~~	~~M~~	~~MM~~	~~Gadus morhua~~	~~MHF~~	~~1~~	~~Vert3~~	~~-24.77~~	-	-	~~5.62~~	-	NA		~~GAM:84424:559:2~~			~~0,205~~	~~0,5~~

~~408~~	~~Bua Västergård~~	~~M~~	~~MM~~	~~Molva molva~~	~~MHF~~	~~1~~	~~Vert~~	-			-		NA		~~GAM:84424:1451:2~~			~~0,055~~	~~1~~
~~409~~	~~Bua Västergård~~	~~M~~	~~MM~~	~~Gadus morhua~~	~~MHF~~	~~1~~	~~Vert~~	-			-		NA		~~GAM:84424:736:1~~			-	~~0,5~~
~~410~~	~~Bua Västergård~~	~~M~~	~~MM~~	~~Molva molva~~	~~MHF~~	~~1~~	~~Vert~~	~~-24.84~~	~~-16.77~~	~~12.364~~	~~9.33~~	~~0.88~~	NA		~~GAM:84424:1678:2~~			~~0,202~~	~~1~~
~~411~~	~~Gisslause~~	~~F~~	~~EM~~	~~Esox lucius~~	~~PIK~~	~~4~~	~~Clei, Vert, Denta, P.sph~~	~~-19.91~~	~~-0.64~~	~~3.985~~	~~2.27~~	~~0.66~~	NA	~~101/199~~	~~3a,b,c~~			~~0,955~~	~~0,43~~
~~412~~	~~Gisslause~~	~~F~~	~~EM~~	~~Cyprinidae~~	~~CYP~~	~~8~~	~~Vert cau, Phar, Vert1~~	~~-16.71~~	~~-3.15~~	~~2.747~~	~~2.3~~	~~0.97~~	NA	~~100/200~~	~~4b, 4a~~			~~0,538~~	~~0,39~~
~~413~~	~~Gisslause~~	~~F~~	~~EM~~	~~Perca fluviatilis~~	~~FMF~~	~~6~~	~~Vert, dent~~	~~-18.54~~	~~-2.83~~	~~2.056~~	~~1.51~~	~~0.85~~	NA	~~103/199~~	~~6,b,b,c,c,c,c~~			~~0,62~~	~~0,34~~
414	Gisslause	F	EM	Cyprinidae	CYP	8	Vert, Phar	-17.43	3.04	3.078	3.7	1.4	NA	100/200, 201	5b,d,b			0,925	0,26
~~415~~	~~Gisslause~~	~~F~~	~~EM~~	~~Lota lota~~	~~FMF~~	~~10~~	~~Vert, Quad~~	~~-19.87~~	~~-0.83~~	~~2.597~~	~~1.61~~	~~0.72~~	NA	~~103/199~~	~~8b,c~~			~~0,749~~	~~0,51~~
~~416~~	~~Gisslause~~	~~F~~	~~EM~~	~~Lota lota~~	~~FMF~~	~~5~~	~~Vert~~	~~-22.17~~	~~-7.53~~	~~4.882~~	~~1.43~~	~~0.34~~	NA	~~103/199~~	~~7a,d~~			~~0,992~~	~~0,53~~
417	Haväng	F	EM	Alces alces	THE	1	cornu	-22.47	3.36	3.264	7.67	2.74	NA	NA	NA			1,099	NA
UB23792	Sunnansund	F	EM	Homo sapiens		1	Ph 2	-19.01	13.32	3.41		NA	NA	NA					
UB23795	Sunnansund	F	EM	Homo sapiens		1	Cra	-21.85	13.12	3.68		NA	NA	NA					

Table S 3 Isotope data other studies. F=Freshwater; M=Marine; EM=Early MesolithicM; MM=Middle Mesolithic.

Country	Culture epoch	Site name	Taxon	Environment	Source	Code name	δ13C	δ15N	C:N	Bone Element	%C	%N	Reference	Lab number
Sweden	MM	Motala Strandvägen	Hedgehog	F	Terrestrial omnivore	TOM	-19.3	7.3	3.40	Mandibula	40.2	13.8	Eriksson et al 2016	MOT 105
Sweden	MM	Motala Strandvägen	Wild boar	F	Terrestrial omnivore	TOM	-21.4	5.5	3.50	Dens (M3)	39.4	13.3	Eriksson et al 2016	MOT 045
Sweden	MM	Motala Strandvägen	Wild boar	F	Terrestrial omnivore	TOM	-20.9	4	3.30	Tibia	42.5	14.9	Eriksson et al 2016	MOT 028
Sweden	MM	Motala Strandvägen	Wild boar	F	Terrestrial omnivore	TOM	-21.5	3.8	3.60	Astragalus	39	12.7	Eriksson et al 2016	MOT 027
Sweden	MM	Motala Strandvägen	Wild boar	F	Terrestrial omnivore	TOM	-21.4	5.3	3.50	Humerus	41.5	13.8	Eriksson et al 2016	MOT 026
Sweden	MM	Motala Strandvägen	Wild boar	F	Terrestrial omnivore	TOM	-21.6	4.4	3.40	Humerus	37.3	12.8	Eriksson et al 2016	MOT 010
Sweden	MM	Motala kanaljorden	Wild boar	F	Terrestrial omnivore	TOM	-22.6	5.3	3.40	Tibia	36.7	12.5	Eriksson et al 2016	MKA 88
Sweden	MM	Motala kanaljorden	Brown bear	F	Terrestrial omnivore	TOM	-20.6	4.5	3.30	Humerus	40.6	14.5	Eriksson et al 2016	MKA 65
Sweden	MM	Motala kanaljorden	Wild boar	F	Terrestrial omnivore	TOM	-20.9	4.8	3.40	Coxae	40.7	13.9	Eriksson et al 2016	MKA 63
Sweden	MM	Motala kanaljorden	Wild boar	F	Terrestrial omnivore	TOM	-20.5	5.5	3.30	Astragalus	38.6	13.7	Eriksson et al 2016	MKA 62
Sweden	MM	Motala kanaljorden	Brown bear	F	Terrestrial omnivore	TOM	-20.4	6.1	3.40	Humerus	42.5	14.6	Eriksson et al 2016	MKA 58
Sweden	MM	Motala kanaljorden	Brown bear	F	Terrestrial omnivore	TOM	-20.8	4.5	3.20	Ulna	40.7	14.7	Eriksson et al 2016	MKA 56
Sweden	MM	Motala kanaljorden	Brown bear	F	Terrestrial omnivore	TOM	-20.5	4.7	3.30	Ulna	41.5	14.8	Eriksson et al 2016	MKA 55
Sweden	MM	Motala kanaljorden	Wild boar	F	Terrestrial omnivore	TOM	-22	5.3	3.50	Vertebrae	39	13.1	Eriksson et al 2016	MKA 52
Sweden	MM	Motala kanaljorden	Wild boar	F	Terrestrial omnivore	TOM	-21.2	6.1	3.30	Mandibula	40.9	14.6	Eriksson et al 2016	MKA 47
Sweden	MM	Motala kanaljorden	Brown bear	F	Terrestrial omnivore	TOM	-20.1	5.5	3.30	Humerus	40.5	14.4	Eriksson et al 2016	MKA 45+46
Sweden	MM	Motala kanaljorden	Wild boar	F	Terrestrial omnivore	TOM	-21.7	4.9	3.50	Vertebrae	35.2	11.6	Eriksson et al 2016	MKA 44
Sweden	MM	Motala kanaljorden	Wild boar	F	Terrestrial omnivore	TOM	-21.8	4.9	3.40	Calcaneus	40.3	13.9	Eriksson et al 2016	MKA 43
Sweden	MM	Motala kanaljorden	Brown bear	F	Terrestrial omnivore	TOM	-20.5	6.2	3.30	Dens (I3)	40.7	14.5	Eriksson et al 2016	MKA 40

Sweden	MM	Motala kanaljorden	Wild boar	F	Terrestrial omnivore	TOM	-21.1	4.7	3.30	Dens (P2)	39.5	14.1	Eriksson et al 2016	MKA 39
Sweden	MM	Motala kanaljorden	Brown bear	F	Terrestrial omnivore	TOM	-20.5	6.1	3.20	Dens (I3)	41.3	14.9	Eriksson et al 2016	MKA 38
Sweden	MM	Motala kanaljorden	Wild boar	F	Terrestrial omnivore	TOM	-27.5	8.4	3.50	Cranium	38.6	13	Eriksson et al 2016	MKA 12
Sweden	MM	Motala Strandvägen	Roe deer	F	Terrestrial Herbivore	THE	-22.8	3.9	3.40	Astragalus	40.2	14	Eriksson et al 2016	MOT 111
Sweden	MM	Motala Strandvägen	Beaver	F	Terrestrial Herbivore	THE	-22.4	4.1	3.40	Dens (M)	38.3	12.9	Eriksson et al 2016	MOT 104
Sweden	MM	Motala Strandvägen	Roe deer	F	Terrestrial Herbivore	THE	-21.9	6.3	3.40	Dens (M2)	38.4	13.1	Eriksson et al 2016	MOT 103
Sweden	MM	Motala Strandvägen	Red deer	F	Terrestrial Herbivore	THE	-21.9	6.1	3.30	Dens (P)	38.7	13.6	Eriksson et al 2016	MOT 101
Sweden	MM	Motala Strandvägen	Red deer	F	Terrestrial Herbivore	THE	-21.8	5.6	3.50	Dens (M2)	36.3	12.1	Eriksson et al 2016	MOT 043
Sweden	MM	Motala Strandvägen	Roe deer	F	Terrestrial Herbivore	THE	-22.4	3.1	3.40	Mandibula	42.6	14.6	Eriksson et al 2016	MOT 039
Sweden	MM	Motala Strandvägen	Red deer	F	Terrestrial Herbivore	THE	-21.8	3.9	3.40	Astragalus	36.3	12.4	Eriksson et al 2016	MOT 036
Sweden	MM	Motala Strandvägen	Elk	F	Terrestrial Herbivore	THE	-21.6	4.6	3.40	Dens (I)	40.1	13.7	Eriksson et al 2016	MOT 033
Sweden	MM	Motala Strandvägen	Beaver	F	Terrestrial Herbivore	THE	-21.8	3.9	3.40	Femur	34.6	11.8	Eriksson et al 2016	MOT 007
Sweden	MM	Motala kanaljorden	Red deer	F	Terrestrial Herbivore	THE	-21.7	2.7	3.30	Antler	40.8	14.2	Eriksson et al 2016	MKA 64
Sweden	MM	Motala kanaljorden	Elk	F	Terrestrial Herbivore	THE	-20.8	1.8	3.30	Radius	42.6	14.9	Eriksson et al 2016	MKA 57
Sweden	MM	Motala kanaljorden	Elk	F	Terrestrial Herbivore	THE	-22.1	3.5	3.30	Astragalus	42.4	15	Eriksson et al 2016	MKA 53
Sweden	MM	Motala kanaljorden	Elk	F	Terrestrial Herbivore	THE	-21.5	1.9	3.30	Radius	41.9	14.8	Eriksson et al 2016	MKA 49
Sweden	TM	Ageröd I	Bos primigenius	F	Terrestrial Herbivore	THE	-22.3	6	3.30	NA	42.2	15.1	Eriksson 2003	Age 20
Sweden	TM	Ageröd I	Bos primigenius	F	Terrestrial Herbivore	THE	-23.1	6	3.60	NA	40.5	13.2	Eriksson 2003	age 19
Sweden	TM	Ageröd I	Alces alces	F	Terrestrial Herbivore	THE	-22.3	2.6	3.30	NA	43	15.3	Eriksson 2003	AGE 18
Sweden	TM	Ageröd I	Alces alces	F	Terrestrial Herbivore	THE	-22.7	5.1	3.40	NA	42.4	14.7	Eriksson 2003	Age 17
Sweden	MM	Motala Strandvägen	Eel	F	Freshwater Cata-/Anadromous fish	FCA	-14.9	10.7	3.30	Vertebrae	40.5	14.5	Eriksson et al 2016	MOT 107
Sweden	MM	Motala kanaljorden	Pike	F	Pike	PIK	-17.9	9.7	3.60	Vertebrae	33.1	10.8	Eriksson et al 2016	MKA 73
Sweden	MM	Motala kanaljorden	Perch	F	Freshwater Mid-trophic Fish	FMF	-15.1	10	3.40	Frontale	29.7	10.1	Eriksson et al 2016	MKA 71
Denmark	MMSM	Storelyng	Pike	F	Pike	PIK	-25.9	6.6	3.40	Articulare	42	14.3	Fischer et al 2007	AF9440

Denmark	MMSM	Storelyng	Pike	F	Pike	PIK	-24	7.8	3.20	Vertebrae	37.6	13.9	Fischer et al 2007	AF9093
Denmark	SM	Bøgebjerg	Pike	M	Pike	PIK	-23.1	12.5	3.30	Vertebrae	29.2	10.3	Fischer et al 2007	AAR-8855
Denmark	TM	Holmegård	Pike	F	Pike	PIK	-22.8	10	3.60	Vertebrae	43.4	14.1	Fischer et al 2007	1944-38D
Denmark	TM	Holmegård	Pike	F	Pike	PIK	-15.4	7.8	3.60	Articulare	33.8-39.8	11.7-12.9	Fischer et al 2007	AAR8854/1922C
Denmark	TM	Mullerup	Pike	F	Pike	PIK	-9.3	9.4	3.60	Vertebra	35.8	11.8	Fischer et al 2007	BCH198:21a+b
Denmark	TM	Mullerup	Pike	F	Pike	PIK	-9.5	8.7	3.60	Dentale	41.3	13.3	Fischer et al 2007	6/ACQ59:92+42
Denmark	TM	Mullerup	Pike	F	Pike	PIK	-20.7	11.9	3.50	Vertebrae	10.6	2.2	Fischer et al 2007	10/ACQ66a:28+52
Denmark	TM	Mullerup	Pike	F	Pike	PIK	-8	9.2	3.40	Vertebrae	42.6	14.6	Fischer et al 2007	5/ACQ59:19+40
Denmark	TM	Mullerup,	Pike	F	Pike	PIK	-9.5	8.7	3.30	Cleithrum	39.6	14.2	Fischer et al 2007	9/ACQ66a:24+43
Denmark	MM	Argus	Pike	M	Pike	PIK	-11.2	10.6	3.40	Vertebrae	24.6	8.6	Fischer et al 2007	AAR-8605
Denmark	MM	Argus	Pike	M	Pike	PIK	-13.3	11.8	3.50	Vertebrae	42.8	14.2	Fischer et al 2007	AAR-8605
Sweden	TM	Huseby Klev	Lagenorhynchus	M	Marine_Aqua_mammal	MAM	-13.6	15.5	3.30	Vertebrae	41.3	14.7	Eriksson 2003	HUS06
Denmark	MM	Argus	Grey seal	M	Marine_Aqua_mammal	MAM	-15.5	15.5	3.30	Cranium	34.2	12.3	Fischer et al 2007	AAR-8608
Denmark	MM	Argus	Harp seal	M	Marine_Aqua_mammal	MAM	-16.8	12.1	3.20	Cranium	35.7-47.7	12.9-17.6	Fischer et al 2007	AAR-8609
Sweden	MM	Tågerup	Eel	M	Marine Cata-/Anadromous fish	MCA	-13.57	8.98	3.60	Vertebrae	40.76	13.22	Robson et al. 2015	TA1.9a
Sweden	MM	Tågerup	Eel	M	Marine Cata-/Anadromous fish	MCA	-11.92	8.95	3.40	Vertebrae	64.27	22.29	Robson et al. 2015	TA1.6a+b
Denmark	SM	Nederst	Pleuronectidae	M	Marine Low trophic fish	MLF	-10.38	7.5	3.29	Vertebrae	42.31	15.02	Robson et al. 2015	NSIP5a+b
Denmark	SM	Nederst	Pleuronectidae	M	Marine Low trophic fish	MLF	-8.08	6.54	3.45	Vertebrae	44.34	14.98	Robson et al. 2015	NSIP4
Denmark	SM	Nederst	Gadidae	M	Marine high trophic fish	MLF	-7.82	9.72	3.30	Vertebrae	43.17	15.26	Robson et al. 2015	NSIG5a+b
Denmark	SM	Nederst	Gadidae	M	Marine high trophic fish	MLF	-11.34	11.31	3.44	Vertebrae	28.53	9.66	Robson et al. 2015	NSIG3a+b
Denmark	SM	Nederst	Eel	M	Marine Cata-/Anadromous fish	MCA	-10.04	9.27	3.49	Vertebrae	41.58	13.9	Robson et al. 2015	NSIE6a
Denmark	SM	Nederst	Eel	M	Marine Cata-/Anadromous fish	MCA	-8.47	8.03	3.40	Vertebrae	40.58	13.93	Robson et al. 2015	NSIE5a+b
Denmark	SM	Nederst	Eel	M	Marine Cata-/Anadromous fish	MCA	-9.37	8.7	3.49	Vertebrae	43.09	14.42	Robson et al. 2015	NSIE3a
Denmark	SM	Nederst	Eel	M	Marine Cata-/Anadromous fish	MCA	-8.41	8.83	3.31	Vertebrae	46.85	16.52	Robson et al. 2015	NSIE12a+b
Denmark	SM	Havnø	Eel	M	Marine Cata-/Anadromous fish	MCA	-10.1	9.3	3.30	Vertebrae	62.9	22.6	Robson et al. 2012	HAV5.16a+b
Denmark	SM	Havnø	Eel	M	Marine Cata-/Anadromous fish	MCA	-7.9	9.8	3.20	Vertebrae	33.3	12.2	Robson et al. 2012	HAV5.14a+b+c
Denmark	SM	Havnø	Eel	M	Marine Cata-/Anadromous fish	MCA	-6.9	7.4	3.30	Vertebrae	42.5	14.8	Robson et al. 2012	HAV4.2a
Denmark	SM	Havnø	Eel	M	Marine Cata-/Anadromous fish	MCA	-7.7	8.5	3.20	Vertebrae	91.6	33.7	Robson et al. 2012	HAV4.1a+b
Denmark	SM	Havnø	Eel	M	Marine Cata-/Anadromous fish	MCA	-9	8.4	3.30	Vertebrae	59.6	21.1	Robson et al. 2012	HAV3.1a
Denmark	SM	Havnø	Eel	M	Marine Cata-/Anadromous fish	MCA	-9	7.8	3.40	Vertebrae	34.4	12	Robson et al. 2012	HAV2.2a+b
Denmark	SM	Havnø	Eel	M	Marine Cata-/Anadromous fish	MCA	-8.6	7.7	3.30	Vertebrae	39.1	14	Robson et al. 2012	HAV2.1a
Denmark	SM	Havnø	Eel	M	Marine Cata-/Anadromous fish	MCA	-9.7	7.9	3.40	Vertebrae	34.8	12.1	Robson et al. 2012	HAV1.4a
Denmark	SM	Havnø	Eel	M	Marine Cata-/Anadromous fish	MCA	-9.8	7.9	3.40	Vertebrae	25.5	8.8	Robson et al. 2012	HAV1.2a
Denmark	SM	Dragsholm	Spurdog	M	Marine high trophic fish	MHF	-14.04	11.65	3.58	Vertebrae	49.03	15.99	Robson et al. 2015	DS6a+b
Denmark	SM	Dragsholm	Spurdog	M	Marine high trophic fish	MHF	-12.73	10.15	3.61	Vertebrae	42.72	13.81	Robson et al. 2015	DS3a+b
Denmark	SM	Dragsholm	Pleuronectidae	M	Marine Low trophic fish	MHF	-16.55	7.23	3.44	Vertebrae	30.08	10.19	Robson et al. 2015	DP5a+b
Denmark	SM	Dragsholm	Pleuronectidae	M	Marine Low trophic fish	MHF	-11.84	7.14	3.48	Vertebrae	39.32	13.19	Robson et al. 2015	DP3a+b
Denmark	SM	Dragsholm	Mackerel	M	Marine Low trophic fish	MHF	-15.38	9.61	3.34	Vertebrae	36.39	12.71	Robson et al. 2015	DM2a+b

Denmark	SM	Dragsholm	Mackerel	M	Marine Low trophic fish	MHF	-15.43	12.34	3.44	Vertebrae	38.53	13.08	Robson et al. 2015	DM1a+b
Denmark	SM	Dragsholm	Garfish	M	Marine high trophic fish	MHF	-13.18	12.67	3.47	Vertebrae	29.79	10.01	Robson et al. 2015	DG3a+b
Denmark	SM	Dragsholm	Garfish	M	Marine high trophic fish	MHF	-13.69	11.92	3.42	Vertebrae	31.28	10.67	Robson et al. 2015	DG1a+b
Denmark	SM	Dragsholm	Eel	M	Marine Cata-/Anadromous fish	MCA	-9.08	9.6	3.47	Vertebrae	35.78	12.02	Robson et al. 2015	DE3a
Denmark	SM	Dragsholm	Eel	M	Marine Cata-/Anadromous fish	MCA	-8.92	9.01	3.63	Vertebrae	25.69	8.26	Robson et al. 2015	DE1
Denmark	SM-N	Asnæs Havnemark	Salmonidae	M	Marine Cata-/Anadromous fish	MCA	-15.49	11.29	3.46	Vertebrae	42.25	12.54	Robson et al. 2015	AHST3a
Denmark	SM-N	Asnæs Havnemark	Pleuronectidae	M	Marine Low trophic fish	MLF	-15.45	8.48	3.44	Vertebrae	27.37	9.27	Robson et al. 2015	AHP2a+b
Denmark	SM-N	Asnæs Havnemark	Mackerel	M	Marine Low trophic fish	MLF	-15.31	11.2	3.38	Vertebrae	36.07	12.45	Robson et al. 2015	AHM2a+b
Denmark	SM-N	Asnæs Havnemark	Mackerel	M	Marine Low trophic fish	MLF	-15.78	11.32	3.39	Vertebrae	35.62	12.27	Robson et al. 2015	AHM1a+b
Denmark	SM-N	Asnæs Havnemark	Eel	M	Marine Cata-/Anadromous fish	MCA	-10.54	10.2	3.37	Ceratohyal	28.9	10.01	Robson et al. 2015	AHE6a
Denmark	SM-N	Asnæs Havnemark	Eel	M	Marine Cata-/Anadromous fish	MCA	-10.04	10.09	3.31	Ceratohyal	30.1	10.61	Robson et al. 2015	AHE2a+b
Denmark	SM-N	Asnæs Havnemark	Gadidae	M	Marine high trophic fish	MHF	-14.22	11.56	3.33	vertebrae	31.09	10.88	Robson et al. 2015	AHC6a+b
Denmark	SM-N	Asnæs Havnemark	Gadidae	M	Marine high trophic fish	MHF	-12.71	11.45	3.40	vertebrae	30.02	10.32	Robson et al. 2015	AHC3a+b
Denmark	SM	Vængesø	Cod	M	Marine high trophic fish	MHF	-8.8	9.9	3.30	Praemax	33.5	12	Fischer et al 2007	AFVS3
Denmark	SM	Vængesø	Cod	M	Marine high trophic fish	MHF	-11.5	10.4	3.30	Parasphen	38.2	13.5	Fischer et al 2007	AFVS2
Denmark	SM	Vængesø	Cod	M	Marine high trophic fish	MHF	-9.9	9.9	3.20	Vertebrae	36.2	13.1	Fischer et al 2007	AFVS1
Denmark	SM	Bjørnsholm	Cod	M	Marine high trophic fish	MHF	-11.6	11.1	3.40	Vertebrae	41.6	14.5	Fischer et al 2007	AFADSC3
Denmark	SM	Bjørnsholm	Cod	M	Marine high trophic fish	MHF	-9.5	10.1	3.20	Vertebrae	39.1	14.4	Fischer et al 2007	AFADSC2
Denmark	SM	Bjørnsholm	Cod	M	Marine high trophic fish	MHF	-9.8	9.7	3.30	Vertebrae	36.9	13.1	Fischer et al 2007	AFADSC1
Denmark	SM	Vængesø	Cod	M	Marine high trophic fish	MHF	-13.3	13	3.40	Vertebrae	37.3	12.9	Fischer et al 2007	ACQ59:
Denmark	SM	Vængesø	Cod	M	Marine high trophic fish	MHF	-9.1	9.5	3.20	Vertebrae	37.2	13.4	Fischer et al 2007	ACQ59:
Denmark	SM	Nivågård	Flounder	M	Marine Low trophic fish	MHF	-13.1	6.5	3.30	Vertebrae	40.3	14.4	Fischer et al 2007	AAR-8861-3/Niv-2
Denmark	SM	Nivågård	Cod	M	Marine high trophic fish	MHF	-12.3	8.8	3.30	Vertebrae	32.5	11.6	Fischer et al 2007	AAR-8860-3/Niv-1,1
Sweden	TM	Ageröd I	roe deer	F	Terrestrial Herbivore	THE	-22.8	2.9	3.60	NA	27.2	8.8	Eriksson 2003	age 26
Sweden	TM	Ageröd I	roe deer	F	Terrestrial Herbivore	THE	-22.4	3.2	3.30	NA	43.5	15.2	Eriksson 2003	age 25
Sweden	TM	Ageröd I	roe deer	F	Terrestrial Herbivore	THE	-23	3.8	3.30	NA	42.8	15.2	Eriksson 2003	age 23
Sweden	TM	Ageröd I	roe deer	F	Terrestrial Herbivore	THE	-22	3.7	3.30	NA	42.2	15.1	Eriksson 2003	age 22
Sweden	TM	Ageröd I	red deer	F	Terrestrial Herbivore	THE	-22	4.8	3.30	NA	42.1	14.9	Eriksson 2003	age 21
Sweden	TM	Ageröd I	brown bear	F	Terrestrial omnivore	TOM	-20.7	3.4	3.30	NA	42.1	15	Eriksson 2003	age 16
Sweden	TM	Ageröd I	brown bear	F	Terrestrial omnivore	TOM	-20.5	3.9	3.30	NA	41.9	14.7	Eriksson 2003	age 15
Sweden	TM	Ageröd I	wild boar	F	Terrestrial omnivore	TOM	-21.3	4.6	3.40	NA	30.6	10.6	Eriksson 2003	age 13
Sweden	TM	Ageröd I	wild boar	F	Terrestrial omnivore	TOM	-21.3	4.5	3.40	NA	41.4	14.2	Eriksson 2003	age 12
Sweden	TM	Ageröd I	red deer	F	Terrestrial Herbivore	THE	-22.9	3.4	3.30	NA	38.6	13.8	Eriksson 2003	age 06
Denmark	TM	Holmegård	Roe deer	F	Terrestrial Herbivore	THE	-22.6	3.1	3.40	Femur	44.6	15.2	Fischer et al 2007	AAR-8659-2/1922
Denmark	TM	Holmegård	Roe deer	F	Terrestrial Herbivore	THE	-24.3	3.8	3.40	Femur	45.3	15.7	Fischer et al 2007	AAR-8659-1/1922

Denmark	TM	Holmegård	Red deer	F	Terrestrial Herbivore	THE	-22.7	4.7	3.40	Femur	44.3	15.1	Fischer et al 2007	AAR-8658-1/1922
Denmark	TM	Holmegård	Red deer	F	Terrestrial Herbivore	THE	-22.9	4.6	3.30	Femur	40.9	14.3	Fischer et al 2007	AAR-8658-2/1922
Denmark	MM	Argus	Red deer	M	Terrestrial Herbivore	THE	-22.6	4.9	3.30	Humerus	34.2-40.7	12.5-14.5	Fischer et al 2007	AAR-8611
Denmark	MM	Argus	Red deer	M	Terrestrial Herbivore	THE	-23.6	4.6	3.50	Humerus	42.9	14.4	Fischer et al 2007	AAR-8611-2
Denmark	MM	Argus	Red deer	M	Terrestrial Herbivore	THE	-21.5	6	3.30	Humerus	42.5	15.1	Fischer et al 2007	AAR-8611-3
Denmark	MM	Argus	Roe deer	M	Terrestrial Herbivore	THE	-23.5	3.9	3.30	Femur	35.5-44.4	12.9-15.7	Fischer et al 2007	AAR-8610
Denmark	MM	Argus	Roe deer	M	Terrestrial Herbivore	THE	-24	5	3.30	Femur	43.2	15.3	Fischer et al 2007	AAR-8610-2
Denmark	MM	Argus	Roe deer	M	Terrestrial Herbivore	THE	-22.8	4.6	3.20	Femur	43.7	15.8	Fischer et al 2007	AAR-8610-3
Sweden	TM	Ageröd I	grey seal	F	Fresh_Aqua_mammal	FAM	-19.3	11.9	3.30	NA	42.3	15	Eriksson 2003	age 14

Modern Isotope data on plants and mushrooms. Original data without added 2‰ to the δ^{13}Cvalues to account for the Suess-effect.

Poland	Modern	Białowieża Forest	Bilberry, Lingonberry	Vaccinium sp.	Berries	BER	-32.2±0.7	-5.7±0.5	6	Selva et al., 2012
Poland	Modern	Białowieża Forest	Raspberry	Rubus idaeus	Fruits	FRU	-29.9	-1.9	1	Selva et al., 2012
Poland	Modern	Białowieża Forest	Apple	Malus sp.	Fruits	FRU	-28.5,-30.1	4.2, 2.3	2	Selva et al., 2012
Poland	Modern	Białowieża Forest	Bird cherry	Prunus padus	Fruits	FRU	-27.3	-0.6	1	Selva et al., 2012
Poland	Modern	Białowieża Forest	Edible currants	Ribes sp.	Fruits	FRU	-27.8	-1.1	1	Selva et al., 2012
Poland	Modern	Białowieża Forest	Mushrooms	Fungi sp.	Mushrooms	MUS	-22.2±0.3	-0.2±0.7	6	Selva et al., 2012
Poland	Modern	Białowieża Forest	Hazelnut	Corylus avellana	Hazelnuts	HAZ	-32.6±0.6	-0.6±0.4	10	Selva et al., 2012

Table S 4 Protein scaling data. The amount of protein and energy in 100 g flesh from species with available data in the source category. * Data from: Swedish National Food Agency (livsmedelsverket). ** Data from: USDA Food Composition Databases

Terrestrial Herbivore	Species	Red deer (Cervus elaphus) *	Beaver (Castor fiber) **	Elk (Alces alces) **		**Average**
	Protein (g)	22,31	24,05	22,24		
	Energy (kcal)	108	146	102		
	% protein of energy (g/kcal)	20,66%	16,47%	21,80%		**19,64%**
Terrestrial Omnivores	Species	Wild boar (Sus scrofa) **	Bear (Ursidae sp.)**			
	Protein (g)	21,51	20,1			
	Energy (kcal)	122	161			
	% protein of energy (g/kcal)	17,63%	12,48%			**15,06%**
Freshwater Aquatic Mammal	Species	Ringed seal (Pusa hispida)**				
	Protein (g)	28,4				
	Energy (kcal)	142				
	% protein of energy (g/kcal)	20,00%				**20,00%**
Marine Aquatic Mammal	Species	Ringed seal (Pusa hispida)**				
	Protein (g)	28,4				
	Energy (kcal)	142				
	% protein of energy (g/kcal)	20,00%				**20,00%**
Berries	Species	Billberry (Vaccinium myrtillus)*	Lingonberry (Vaccinium vitis-idaea)*			
	Protein (g)	0,7	0,7			
	Energy (kcal)	53	57			
	% protein of energy (g/kcal)	1,32%	1,23%			**1,27%**
Fruits	Species	Raspberry (Rubus idaeus)*	Apple (Malus sp.)**	Cherry (Prunus avium)*	Currant (Ribes sp.)**	
	Protein (g)	1,2	0,23	1,09	1,4	
	Energy (kcal)	34	48	69	63	
	% protein of energy (g/kcal)	3,53%	0,48%	1,58%	2,22%	**1,95%**
Hazelnuts	Species	Hazelnut*				
	Protein (g)	13				
	Energy (kcal)	656				
	% protein of energy (g/kcal)	1,98%				**1,98%**
Mushrooms	Species	Chanterelle (Cantharellus cibarius) *	Champignon mushroom (Agaricus bisporus)*			
	Protein (g)	1,71	2,38			
	Energy (kcal)	24	27			
	% protein of energy (g/kcal)	7,13%	8,81%			**7,97%**

Pike	Species	Northern pike (Esox lucius) *		
	Protein (g)	20,25		
	Energy (kcal)	84		
	% protein of energy (g/kcal)	24,11%		**24,11%**
Freshwater Mid-trophic Fish	Species	Perch (Perca fluviatilis) *	Burbot (Lota lota)*	
	Protein (g)	19,81	16,51	
	Energy (kcal)	86	71	
	% protein of energy (g/kcal)	23,03%	23,25%	**23,14%**
Cyprinids	Species	Bream (Abramis brama)*	Carp (Cyprinus carpio)**	
	Protein (g)	16,7	17,83	
	Energy (kcal)	103	127	
	% protein of energy (g/kcal)	16,21%	14,04%	**15,13%**
Freshwater Cata-/Anadromous fish	Species	Eel (Anguilla anguilla)*		
	Protein (g)	14,6		
	Energy (kcal)	353		
	% protein of energy (g/kcal)	4,14%		**4,14%**
Marine High-trophic Fish	Species	Cod (Gadus morhua)*	Ling (Molva molva) **	
	Protein (g)	18,19	18,99	
	Energy (kcal)	78	87	
	% protein of energy (g/kcal)	23,32%	21,83%	**22,57%**
Marine Low-trophic Fish	Species	Flounder (Platichthys sp.)*	Mackerel (Scomber scombrus)*	
	Protein (g)	18,3	17	
	Energy (kcal)	94	298	
	% protein of energy (g/kcal)	19,47%	5,70%	**12,59%**
Marine Cata-/Anadromous fish	Species	Eel (Anguilla anguilla)*	Atlantic salmon (Salmo salar)**	
	Protein (g)	14,6	19,84	
	Energy (kcal)	353	142	
	% protein of energy (g/kcal)	4,14%	13,97%	**9,05%**

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Fishing for ways to thrive

In this publication, life in Early and Middle Mesolithic Scandinavia is explored. Using interdisciplinary methods the author analyses zooarchaeological remains in order to evaluate the subsistence strategies of Early Holocene Scandinavian foragers. The importance of aquatic resources is highlighted, and humans are shown to rely on fish to a higher degree and from an earlier date than previously assumed. These results have implications for how Early Holocene societies are interpreted, and indicate emerging sedentism and growing territoriality were already taking place during the Early Mesolithic period. The emergence of social stratification is therefore conceivable at an early stage of Scandinavian prehistory.

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