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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

Adam Boethius*, Torbjörn Ahlström

Department of Archaeology and Ancient History, Lund University, 223 63 Lund, Sweden

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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

* Corresponding author.
E-mail address: adam.boethius@ark.lu.se (A. Boethius).

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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

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