Dietary diversity and moderate mobility – isotope evidence from Scanian Battle Axe Culture burials

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Human skeletal remains from eight Scanian Battle Axe Culture burial sites have been subjected to stable isotope analyses with the aim of elucidating patterns of diet and mobility. The results reveal diversity in the food sources exploited by the analysed individuals, including varied contributions of marine protein. This suggests that the general association of the BAC with a farming/pastoralist economy needs revision. Further, the majority of the individuals seem to be of local origin, and the level of mobility is generally low.

Keywords: mobility, palaeodiet, stable isotopes, Battle Axe Culture, Neolithic, Scania

Introduction

The Battle Axe Culture (BAC) of the Middle Neolithic B (MN B) in south and central Sweden has traditionally been described as groups of farmers/pastoralists (e.g. Knutsson 1995; Welinder 1998; Malmer 2002). These assumptions are in line with a common perception of the Neolithisation in north-west Europe as representing a sharp dietary shift towards consumption of more or less exclusively (domesticated) terrestrial resources (e.g. Richards et al. 2003b; Rowley-Conwy 2004 and discussions in Whittle & Cummings (eds.) 2007). However, a recent study of Neolithic dietary strategies on the island of Öland in the Baltic Sea found, by looking at stable isotopes, that a diversity in food culture, including marine resources, existed throughout the entire Middle Neolithic period (Eriksson et al. 2008). The Scanian BAC burials are often located only a few kilometres from the coast, so marine resources were readily available for anyone choosing to exploit them. The question is to what extent, if at all, these resources were included in the economy and food culture of the Scanian MN B societies.

The BAC burials and associated artefacts adhere to strict conventions on a wider geographical level, implying the possibility of intense interactions across considerable distances (Malmer 1962, 1975, 2002; Knutsson 1995). Analyses of sulphur and strontium isotopes on the skeletal remains from Öland reveal the presence of mobile and non-local individuals on the island during MN B (Fornander et al. ms.; Linderholm et al. ms.). Does this reflect a common occurrence of intense interaction/movement during MN B in south Scandinavia? Here, skeletal remains from eight BAC burial sites are subjected to stable carbon, nitrogen and sulphur isotope analyses in order to illuminate the choices of economic resources as well as the level of mobility in MN B Scania.

The natural landscape of Scania

The diverse geology of Scania includes a variety of Phanerozoic sedimentary rocks covering the southern and western parts of the province as well as a smaller region in the northeast (Fig. 1). Precambrian crystalline rocks dominated by orthogneiss extend between these two regions, and also cover a more limited area in the south (Loberg 1999).

Although Scania has had a negative shoreline displacement since around 3000 BC of c. 2–3 m in the south, and 5–6 m in the north, the Middle Neolithic Scanian coastline approximately reflects present day conditions. Some of the most significant differences can be found around Kristianstad in NE Scania, where

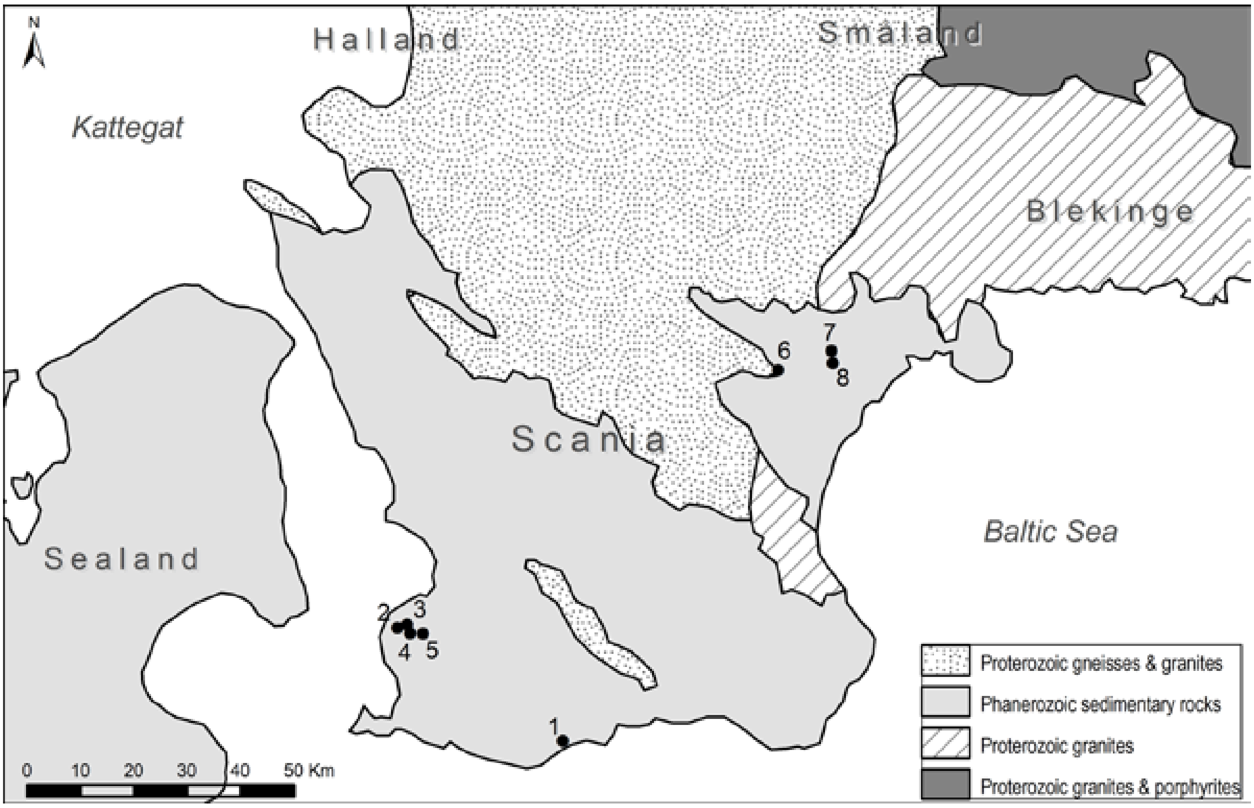

Figure 1. Geological map of Scania indicating analysed sites. 1) Lilla Bedinge, 2) Dösemarken, 3) Norra Hyllievång, 4) Svågertorp, 5) Kastanjegården, 6) Skepparslöv, 7) Åraslöv, 8) Håslöv. Geological data from Loberg (1999).

more land was subdued during the period in question, despite the general land subsidence (according to sea level maps generated from the Geological Survey of Sweden). In the following presentations of the analysed sites, stated distances to the coast refer to present day conditions.

An introduction to the Battle Axe Culture of Scania and beyond

The Battle Axe Culture (BAC) appears in the archaeological record of south, central and west Sweden around 2800 BC, marking the start of the Middle Neolithic B (c. 2800–2300 BC). It represents a regional variation of the continental Corded Ware Culture complex. Specific BAC material culture includes the eponymous boat shaped ground stone axes, in older research often interpreted as battle axes, and rounded beakers with highly regulated decoration. The c. 250 known BAC graves i Sweden, the majority of which are found in Scania, display evidence of strict conventions surrounding the burial practices, reflecting a common tradition within the continental Corded Ware Culture. In the N–S oriented flat earth inhumation graves, where one or two individuals are usually placed in crouching position facing east, grave inventories include beakers and axes placed according to common rules (Malmer 1962, 1975, 2002; Knutsson 1995; Larsson 2009).

Traditionally, the archaeological material from MN B in south and central Sweden has been interpreted as the remains of two different, partly coeval, cultures: the Battle Axe Culture and the Pitted Ware Culture. However, this implied dualism has been widely debated. The distinct features of the BAC have been perceived as either representing a separate group of people with a shared sense of identity or ethnicity, or as reflecting one of several aspects of a wider group of people using different material cultures at different places or on different levels of society (see e.g. reviews and discussions in Larsson 2009, von Hackwitz 2009). Here, the concept of BAC refers to the distinct material culture and burial traditions of the MN B outlined above, and no attempt is made to specify what this culture entails. The main focus here is on gaining insights into dietary and mobility patterns in Scania during the period in question, where the BAC burials present extensive, comparable and relatively well preserved source materials.

The economy of the BAC has been described as based on small-scale farming and (sheep) pastoralism, complemented by inland hunting (e.g. Knutsson 1995;

Malmer 1962, 1975, 2002; Larsson 2009). The fragmentary osteological indices, primarily from Scanian burials, show a dominance of red deer, followed by sheep, among the recovered faunal bones. The rare occurrences of grain impressions in pottery, from Scania and Västmanland, are dominated by barley (Malmer 2002:150p).

Included burial sites

The analysed material originates from eight sites representing three different Scanian regions; the NE, SW and S part of the province, respectively (Fig. 1). The southern region is only represented by one site, Lilla Bedinge, although the majority of the analysed individuals originate from this cemetery. The sites further represent varied proximities to the coast. On the basis of typological chronologies and available radiocarbon dates, the burials are generally attributed to the later part of the Swedish-Norwegian Battle Axe Culture, falling within Malmer's (1962) Periods 3–5 with an emphasis on Period 5, i.e. late MN B. The analysed skeletal material is presented in Table 1.

Lilla Bedinge, Lilla Beddinge parish

Lilla Bedinge in southern Scania contains a large cemetery including at least 14 flat earth inhumation graves. The site is located only about 1 km from the coast. Several different excavations of the inhumation graves (Graves I–XIV, correlating with Graves 41–54 in Malmer 1962) have been carried out between 1915 and 1951 (see further Malmer 1962). According to Malmer (1962:180) three of the inhumation graves, all lacking grave goods, probably date to the Late Neolithic, whereas Grave 47, a mass grave, typologically fall within Period 5 or possibly the Late Neolithic. However, the majority of the graves have been typologically dated to Period 3–5. In the present study, skeletal remains from Graves 47, 49, 52 and 53, representing a total of 16 individuals, are included in the analyses.

Grave 47, a mass grave, comprised a subsurface stone construction, the lower parts of which were distinctly boat shaped. Skeletal remains included a primary burial of a young adult woman placed stretched out on her back. On stratigraphically higher levels, an assemblage of five craniums, representing four adult males and one juvenile/adult of unknown sex, were retrieved. The grave further held the remains of several other individuals, including the remains of two children, located about 0.5 m outside of the stone construction. The few identified finds in Grave 47 consisted of some pottery sherds, one of which was decorated, a bone awl and a lump of red-brown pigment (Malmer 1962:158pp, During 1989). A total of seven individuals from Grave 47 have been analysed in the present study; the five craniums, the primarily buried woman and one of the identified children.

In Grave 49, three adult males had been placed in line, sitting in crouched positions in a chamber covered by flat stone slabs. Further, fragmented remains of two infants, one juvenile and an adult have been identified. The only identified find was a bone needle (Hansen 1934; Malmer 1962:162p; Jantsch & Ranåker 2001; During unpublished notes). All the individuals mentioned from Grave 49 have been included in the analyses.

Grave 52 included two skeletons of young individuals, both of which are analysed in the present study, placed in crouching positions with the heads oriented outwards from the centre of the grave. Whereas the SW individual has been identified as probably being male, the NE skeleton is of unknown sex. Grave goods included four ceramic vessels, two thick bladed hollow edged flint axes, more than 100 amber beads and a comb stamp. Sheep bones were identified in the central parts of the chamber, and a piece of sheet copper, interpreted as an earring, was found by the head of the SW individual (Malmer 1962:168pp; During 1989).

Grave 53 held the remains of an adult male placed in crouching position. Finds include an antler chopping weapon and a thick bladed flint axe. Bones from sheep and golden eagle were retrieved from the burial (Malmer 1962:176pp, During 1989).

Dösemarken, Hyllie parish

The settlement and burial site at Dösemarken is located in SW Malmö, about 2 km from the coast. Archaeological remains indicate a continuous settlement throughout the Neolithic. Apart from the burial with preserved human remains analysed here, three other possible flat earth graves of similar character have been identified during the excavations of the settlement, implying the presence of an associated Middle to Late Neolithic cemetery. In the excavated grave, A1671, a woman aged about 15–18 years had been placed in crouching position. The only burial gift found in association with the body was a bone awl (Ifverson 2007:28–33).

Norra Hyllievång, Hyllie parish

The archaeological site at Norra Hyllievång is located in the southern part of Malmö, about 4 km from the coast. The site display finds and features from the Neolithic, Bronze Age and Early Iron Age. Two graves attributed to the Battle Axe Culture have been investigated at Norra Hyllievång. In grave A14169, included in the present study, the fragmented remains of a young adult individual of undetermined sex, placed in crouching position, were identified. Burial goods included two hollow edged flint axes, a ceramic bowl, one flint blade and a scraper (Lindhé & Grehn 2008).

Svågertorp, Bunkeflo parish

The site at Svågertorp industrial park is located in the southern part of Malmö, about 5 km from the coast. Archaeological remains include two long houses, radiocarbon dated to around the MN A/MN B and LN/BA transitions respectively. The only identified burial on the site (A279) included a brittle but largely intact skeleton of a male aged about 30–39 years placed in crouching position. Burial goods consisted of a bowl shaped vessel, a hollow edged flint axe and a boat axe (Koch & Tuominen 2006).

Kastanjegården, Fosie parish

At Kastanjegården in SW Scania, located about 6.5 km from the coast, four burials have been identified and excavated. Skeletal material analysed in this study originates from one of the three individuals recovered from the partly disturbed Grave 105. Here, the skull and upper torso of a woman aged 25–30 were identified, together with very fragmentary remains of two children. Burial goods included two bowl shaped vessels, a thin bladed flint axe and amber beads (Winge 1976). In this study, only the buried female has been included in the isotope analyses. Previously published stable carbon and nitrogen isotope data from the third molar of this individual has been interpreted as representing a terrestrial diet (Lidén et al. 2004).

Skepparslöv, Skepparslöv parish

A flat earth inhumation grave (Grave 77 in Malmer 1962) was discovered at Skepparlöv, NE Scania, probably in the early 1930s. The site, located about 17 km from the coast, has not been the object of any professional excavation, and only sporadic information about the grave is available. The grave included the relatively well preserved skeletal remains of a child, and grave goods consisted of two ceramic vessels and three zig-zag ornamented bone rings (Forssander 1933, 1934:256; Malmer 1962:921).

Åraslöv, Nosaby parish

In the 1930s, two flat earth inhumation graves were discovered at Åraslöv, NE Scania, about 12 km from the coast. None of the features, discovered at two separate occasions in connection with gravel quarrying, has been professionally excavated. In the first recovered grave (Grave 68 in Malmer 1962), the remains from which are included in the present analyses, a man was found placed stretched out on his back. Identified grave goods included an antler chopping weapon and a thick bladed flint axe (Forssander 1932, 1934; Malmer 1962:920).

Håslöv, Gustav Adolf parish

The burial site at Håslöv, NE Scania, was discovered and investigated at a gravel quarry in 1956. The site is found about 10 km from the coast. Three graves, all of which are included in the present analysis, have been identified at the site. Grave I (Grave 26 in Malmer 1962) held a more or less intact skeleton of an adult male placed in crouching position. The grave goods consisted of a bone awl, a flint blade and an amber bead (Malmer 1962:917, Jantsch & Ranåker 2001:32). Grave II (Grave 27 in Malmer 1962) was severely damaged and, and fragmentary dislocated skeletal remains interpreted as originating from the feature were identified at the bottom of the gravel quarry. No additional finds were identified in association with the grave. Grave III only included a few preserved bone elements (Malmer 1962:917; Jantsch & Ranåker 2001). The individuals from graves II and III have not been determined with regards to sex or age.

The methodology of stable isotopes

Stable carbon and nitrogen isotopes in bone and dentine collagen provide information of an individual's diet in terms of protein intake (DeNiro & Epstein 1978; Ambrose and Norr 1993). Stable carbon isotopes, $\delta^{13}C$, can be applied to discriminate between marine and terrestrial protein consumers in regions, such as Neolithic Scandinavia, where only C_3 plants have been available (Schoeninger & DeNiro 1984). A marine $\delta^{13}C$ end value for the Baltic region has been approximated to c. –15‰, and a terrestrial end value to c. –20‰ (Lidén & Nelson 1994). The nitrogen isotope value, $\delta^{15}N$, is increased by approximately 3‰ for each step up the food chain (Minagawa & Wada 1984; Schoeninger & DeNiro 1984), enabling identification of, for example, herbivorous versus carnivorous diets or consumption of freshwater fish. It should be noted, that since plants have lower protein contents than meat, the vegetable component of a mixed diet will be under-represented in the isotopic data. The trophic level effect can further be used to study patterns of breastfeeding, where the child will develop elevated δ^{15}N values relative to the mother he/she is "preying" on (Fogel et al. 1989).

Stable sulphur isotopes, δ^{34}S, can be applied to study provenience and mobility among archaeological populations. Sulphur in plants predominantly originates from the soil, with a δ^{34}S signature derived from the local bedrock. Resulting from the limited food to consumer isotopic fractionation (c. –1‰ to +2‰), collagen δ^{34}S values reflect the sulphur isotopic composition of the diet, which, in turn, reflects the local sulphur isotope ecology (Peterson et al. 1985; Richards et al. 2003a). Terrestrial sulphur isotopic signatures are thus dependent on the geological setting, where sedimentary rocks are known to exhibit a wide range of δ^{34}S values, ranging between c. –40 and +40‰. European granitic rocks exhibit δ^{34}S values between c. –4 and +9‰, whereas the δ^{34}S values in metamorphic rocks can vary between c. –20 and +20‰ (Faure & Mensing 2005). This terrestrial diversity stands in sharp contrast to marine environments, where the δ^{34}S value of modern ocean water sulphate average 21‰ (Peterson & Fry 1987; Rees et al. 1978). In the estuarine Baltic Sea, however, the δ^{34}S signature will further be affected by freshwater inflow, resulting in lower reported values for marine fauna than in the large oceans (Fornander et al. 2008; Linderholm et al. ms.).

Bone collagen is constantly remodelled during the course of life, with turnover rates of approximately 5–30 years depending on age and bone element (Hedges et al. 2007; Lidén & Angerbjörn 1999). Isotopic data derived from bone thus reflect an average of the last years prior to death. The isotopic record in teeth, on the other hand, is fixed at the time of tooth formation, presenting possibilities to reconstruct an isotopic life history for an individual through analysing both teeth and bone (Sealy et al. 1995; Eriksson 2003).

Analysed skeletal material

A total of 73 bone and teeth samples, representing 25 individuals, were included in the present analyses. From Kastanjegården, the previously published δ^{13}C and δ^{15}N data from a third molar (Lidén et al. 2004) has been included for comparison. The preservation of the skeletal material was highly varied. A total of 12 samples did not produce sufficient collagen and were thus excluded from analysis. Further, two samples did not fulfil the stipulated criteria for unaltered collagen (see below) and are excluded from further discussions. Among the remaining 59 samples, all subjected to δ^{13}C and δ^{15}N analysis and representing 22 individuals, 31 produced sufficient amounts of collagen for δ^{34}S analysis as well. The δ^{34}S analysis consequently includes 19 of the analysed individuals. Collagen samples from eight individuals were further submitted for radiocarbon dating at the Ångström Laboratory in Uppsala. In addition, Torbjörn Ahlström (2009:172) has previously published radiocarbon dates for five of the analysed individuals.

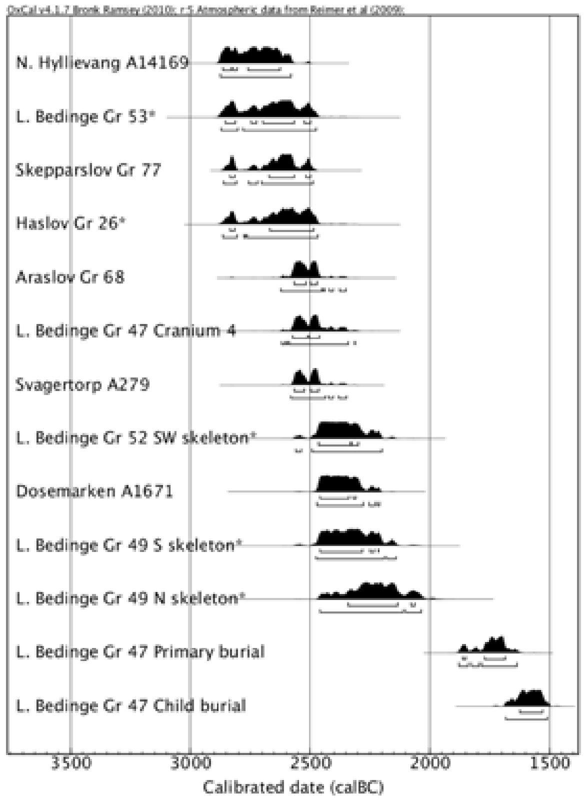

Figure 2. Calibrated radiocarbon data for a selection of the analysed individuals. *Dates previously published by Ahlström (2009:172).

Laboratory procedures

Bone and tooth dentine samples were obtained using a dentist's drill. Tooth samples were taken from the crown of the tooth, via the cervix. Collagen extraction was carried out following a modified Longin method, including removal of fragmented collagen chains and humic substances using a 30 kDa ultra filter (Brown

Table 1. Isotope data for the analysed samples, sorted according to site and individual

Grave/Subject	Age	Sex	^{14}C BP (Subject)	^{14}C lab ID	Lab# stable isotopes	Element	Collagen (mg)	Collagen (%)	δ^{13}C (‰)	δ^{15}N (‰)	% C	% N	C/N	δ^{34}S (‰)	% S	C/S
Lilla Bedinge, L. Beddinge parish																
Grave 47, ”Primary burial”	c. 19 yrs	F	3430±35	Ua-36843	BED 02	M_1	1.4	1.2	–20.1	10.6	40.7	14.6	3.3			
					BED 03	M_2	4.4	1.6	–20.1	10.0	38.9	14.0	3.3	11.1	0.25	415
					BED 06	M_3	0.8	0.8	–20.2	9.9	33.5	12.0	3.3			
					~~BED 05~~	~~Mandible~~	~~0.4~~	~~0.4~~	~~–21.2~~	~~10.2~~	~~40.6~~	~~11.9~~	~~4.0~~			
Grave 47 Cranium 1	35-45 yrs	M			~~BED 15~~	~~Cranium~~	~~0.4~~									
					~~BED 16~~	~~M^1~~	~~0.1~~									
					~~BED 17~~	~~M^2~~	~~0.1~~									
Grave 47 Cranium 2	25-35 yrs	M			~~BED 19~~	~~M_1~~	~~0.3~~									
					BED 30	M_2	0.7	0.7	–19.8	8.4	36.6	12.8	3.3			
					BED 21	M_3	0.6	0.7	–20.4	9.0	35.6	12.0	3.5			
					~~BED 18~~	~~Cranium~~	~~0.1~~									
Grave 47 Cranium 3	Adult?	M			~~BED 22~~	~~Parietal bone~~	~~0.2~~									
Grave 47 Cranium 4	25-35 yrs	M	3975±45	Ua-36842	BED 24	M_1	1.3	1.5	–20.6	9.0	35.9	12.6	3.3			
					BED 32	M_2	1.8	2.6	–20.3	8.9	38.3	13.8	3.2			
					BED 23	Cranium	1.2	1.4	–19.1	9.2	40.7	14.4	3.3	12.1	0.22	493
Grave 47 Cranium 5	Juv./Adult				~~BED 33~~	~~Cranium~~	~~0.1~~									
Grave 47, ”Child burial”	c. 10 yrs		3310±35	Ua-36841	BED 28	dm_1	1.7	3.5	–19.6	12.0	38.4	13.8	3.2			
					BED 09	dc	0.5	2.3	–20.0	11.6	33.3	11.6	3.3			
					BED 29	dm_2	0.9	1.2	–20.1	10.6	35.9	12.5	3.3			
					BED 12	M_1	7.0	2.0	–19.8	10.7	39.6	14.2	3.3	10.8	0.26	406
					BED 13	M_2	1.3	1.4	–20.2	9.9	37.3	13.2	3.3			
					BED 14	M_3 germ	1.3	2.5	–20.3	10.1	37.4	12.9	3.4			

Grave/Subject	Age	Sex	^{14}C BP (Subject)	^{14}C lab ID	Lab# stable isotopes	Element	Collagen (mg)	Collagen (%)	δ^{13}C (‰)	δ^{15}N (‰)	% C	% N	C/N	δ^{34}S (‰)	% S	C/S
					BED 27	Mandible	6.5	1.9	–20.1	10.2	39.6	14.0	3.3	12.1	0.26	406
Grave 49 North skeleton	Adult	M	3790±65*	Ua-19471*	BED 44	M_1	5.6	2.7	–21.3	9.3	34.5	12.0	3.4	11.0	0.21	438
					BED 90	M_2	9.8	4.2	–21.6	8.5	39.8	13.5	3.4	12.7	0.20	530
					BED 46	M_3	7.9	4.0	–21.7	8.9	39.9	13.5	3.5	11.7	0.19	560
					BED 43	Mandible	1.3	1.2	–21.3	8.8	39.9	14.1	3.3			
Grave 49 Middle skeleton	Adult	M			BED 87	M_1	1.1	0.8	–20.7	9.1	35.1	12.7	3.2			
					BED 41	M_2	5.6	6.6	–20.8	9.1	43.0	15.6	3.2	12.0	0.20	573
					BED 42	M_3	4.6	1.9	–20.7	9.4	39.9	14.3	3.3	10.8	0.23	462
					BED 39	Mandible	6.5	1.6	–20.7	9.0	40.3	14.4	3.3	11.2	0.22	488
Grave 49 South skeleton	Adult	M	3860±60*	Ua-19470*	BED 35	M_1	1.6	1.7	–20.8	8.5	39.2	14.0	3.3			
					BED 36	M_2	1.0	1.3	–21.0	8.7	36.8	13.1	3.3			
					BED 37	M_3	2.2	2.4	–20.8	9.2	40.2	14.4	3.3			
					BED 34	Mandible	5.6	0.9	–20.9	9.2	37.9	13.4	3.3	10.7	0.22	459
Grave 49 Infant A	Child				BED 47	Humerus	6.9	2.0	–20.7	10.6	39.2	13.8	3.3	12.1	0.19	550
Grave 49 Infant B	Child				BED 48	Femur	6.1	1.7	–20.9	10.2	38.7	13.1	3.4	11.2	0.21	491
Grave 49 Juvenile C	Juvenile				BED 49	Femur	9.5	2.7	–20.2	10.1	40.8	14.7	3.2	11.9	0.19	572
Grave 52 SW skeleton	c. 14–15 yrs	M?	3890±55*	Ua-19468*	~~BED 52~~	~~M_1~~	~~0.1~~	~~0.1~~								
					~~BED 53~~	~~M_2~~	~~0.1~~	~~0.2~~								
					BED 54	M_3 germ	1.8	2.4	–19.7	10.8	39.4	13.5	3.4			
					BED 51	Mandible	6.3	2.1	–20.1	10.7	41.8	14.7	3.3	12.8	0.20	558
					BED 50	Femur	1.8	1.3	–19.2	11.1	38.5	13.8	3.3			
Grave 52 NE skeleton	c. 12–13 yrs				~~BED 56~~	~~M_1~~	~~0.1~~	~~0.1~~								
					~~BED 57~~	~~M_2~~	~~0.1~~	~~0.2~~								
					~~BED 58~~	~~M^3 germ~~	~~0.3~~	~~0.3~~								
					BED 55	Parietal bone	5.6	1.3	–20.7	10.5	40.8	14.4	3.3	12.2	0.19	572

Grave/Subject	Age	Sex	^{14}C BP (Subject)	^{14}C lab ID	Lab# stable isotopes	Element	Collagen (mg)	Collagen (%)	δ^{13}C (‰)	δ^{15}N (‰)	% C	% N	C/N	δ^{34}S (‰)	% S	C/S
Grave 53	c. 24–29 yrs	M	4080±65*	Ua-19469*	BED 60	M^1	4.6	4.9	–21.3	9.0	42.7	15.5	3.2	10.9	0.18	632
					BED 61	M_2	5.6	5.4	–20.9	9.1	42.0	15.3	3.2	11.4	0.18	621
					BED 62	M_3	5.5	2.2	–20.2	10.3	41.3	14.9	3.2	11.1	0.19	580
					BED 59	Mandible	1.4	1.2	–20.3	10.2	40.1	14.4	3.3			
Dösemarken, Hyllie parish																
Grave A1671	c. 15–18 yrs	F	3885±40	Ua-36844	DOS 01	M_1	2.4	2.0	–19.6	11.9	38.0	13.9	3.2			
					DOS 02	M_2	1.0	0.8	–20.6	10.0	36.7	12.4	3.5			
					DOS 03	M_3	1.8	1.3	–21.0	8.9	36.8	13.3	3.2			
					DOS 04	Mandible	9.2	2.0	–20.9	8.6	38.3	13.8	3.2	10.2	0.24	425
Grave A14169	17–25 yrs		4135±45	Ua-37496	NHY03	Phalanx bone	314.9	1.0	–18.7	10.8	38.0	13.4	3.3			
Svågertorp, Bunkeflo parish																
Grave A279	c. 30–39 yrs	M	3975±35	Ua-36982	~~SVG 02~~	$\cancel{M_1}$	~~0.4~~	~~1.3~~	~~–20.5~~	~~8.5~~	~~32.3~~	~~10.2~~	~~3.7~~			
					SVG 03	M_2	2.2	2.2	–19.9	10.4	39.8	14.1	3.3			
					SVG 04	M_3	2.9	2.8	–20.3	10.3	39.6	13.9	3.3			
					SVG 01	Humerus	12.0	2.3	–20.2	9.4	40.7	14.2	3.3	10.8	0.20	543
Kastanjegården, Fosie parish																
Grave 105	c. 25–30 yrs	F			KAS 03	M_2	0.8	1.3	–21.5	8.3	36.9	12.8	3.4			
					KAS 01**	M^3**			–20.3**	9.8**	36.7**	13.1**	3.3**			
Skepparslöv, Skepparslöv parish																
Grave 77	Child		4075±40	Ua-37497	SKP 04	dm_1	0.3	0.6	–21.6	12.1	35.9	12.1	3.5			
					SKP 01	Long bone	14.4	3.1	–22.1	11.0	41.0	14.6	3.3	8.2	0.23	475
Åraslöv, Nosaby parish																

Grave/Subject	Age	Sex	^{14}C BP (Subject)	^{14}C lab ID	Lab# stable isotopes	Element	Collagen (mg)	Collagen (%)	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	% C	% N	C/N	$\delta^{34}S$ (‰)	% S	C/S
Grav 68 (I)	Adult	M	3990±40	Ua-37494	ARA 02	M_1	4.7	5.4	–19.9	12.3	43.1	15.7	3.2	11.9	0.27	425
					ARA 03	M2	7.7	5.2	–19.8	11.1	42.6	15.4	3.2	12.6	0.27	421
					ARA 04	M3	4.9	4.6	–18.6	12.8	42.7	15.4	3.2	15.3	0.23	495
					ARA 05	Mandible	6.6	7.4	–18.8	12.4	43.2	15.5	3.3	14.7	0.25	461
Håslöv, Gustav Adolf parish																
Grave 26 (I)	Adult	M	4055±60*	Ua-19467*	HAS 02	M_1	2.6	5.2	–20.3	10.8	41.5	15.0	3.2	10.5	0.23	482
					HAS 03	M_2	6.5	5.3	–18.9	11.8	41.4	15.0	3.2	11.0	0.23	480
					HAS 01	Mandible	4.4	4.5	–19.1	11.8	42.2	15.3	3.2	11.5	0.24	469
Grave 27 (II)					HAS 04	Phalanx bone	4.3	5.1	–20.2	11.3	42.6	15.0	3.3	12.6	0.24	473
Grave III					HAS 05	Metatarsal bone	2.7	4.0	–20.8	9.8	41.6	15.0	3.2	9.8	0.31	357

* Radiocarbon dates from Ahlström 2009:172
**Previously published by Lidén et al. 2004

et al. 1988). The carbon and nitrogen isotope analyses were performed by UC Davis Stable Isotope Facility, US, using the EA-IRMS technique. The precision was ±0.4‰ or better for $\delta^{15}N$ and ±0.1‰ or better for $\delta^{13}C$. Sulphur isotopes were analysed at the Iso-Analytical Limited, UK, using the EA-IRMS technique, where the precision was ±0.3 or better.

Collagen quality criteria for the samples include C/N ratios of 2.9–3.6 (DeNiro 1985) as well as C and N concentrations between 15.3–47% and 5.5–17.3% respectively (Ambrose 1990). Sulphur concentrations of 0.14–0.60, together with C/S ratios of 200–800 are assumed to represent unaltered collagen sulphur (Fornander et al. 2008).

Radiocarbon dates for the analysed individuals

In the following, all BC dates refer to a 2σ cal. BC range (OxCal v.4.1.7, Bronk Ramsey 2010). The range for the eight obtained radiocarbon dates is 2875–1509 BC (Table 1 and Fig. 2). The two youngest dates, falling primarily within the Early Bronze Age, represent the primary burial and the child burial in Grave 47 at Lilla Bedinge. The date for the primary burial, 1878–1636 BC, indicates that the grave was constructed around the transition between the Late Neolithic and Early Bronze Age, or later. However, the obtained date for cranium 4, presumably deposited after the woman in the primary burial was interred, is 2620–2310 BC, so these dates are somewhat problematic. Grave 47 deviate from the general pattern of BAC burials in several respects, including the boat shaped stone construction, the stretched out position of the primary burial and the assemblage of clearly disarticulated skulls. It is further interesting to note that the remains of the buried woman displayed deformities of the arms and legs (During 1989). Malmer (1962:180, 2002:141) suggests that the grave should be dated to the end of MN B or, more likely, the Late Neolithic on the basis of the decorated pottery sherd together with the skull assemblage, paralleled in other Scanian Late Neolithic burials. The pottery sherd has been identified as Type J (Malmer 1962:159), and is thus interpreted as belonging to the latest part of the BAC. However, since it was found at the bottom of the boat shaped stone construction, Malmer (2002:141) concludes that it probably came with the filling when the stone boat was built. It may thus represent earlier activities at the site. Therefore, a Late Neolithic date is perhaps more plausible than an attribution of the burial to the Battle Axe Culture. If so, the date for the primary burial is not that problematic, but the fact that one of the craniums yielded an earlier date still needs to be addressed. Perhaps these five skulls, or some of them, represent the disarticulated remains of past members of society, re-deposited in this peculiar burial context. However, we cannot exclude the possibility that there are analytical errors involved here, so the results remain somewhat inconclusive.

Four radiocarbon dates from Lilla Bedinge have further been obtained by Torbjörn Ahlström (2009:172) (Table 1 and Fig. 2), where the north and south skeletons in Grave 49 yielded dates ranging 2459–2037 and 2476–2141 BC, respectively. The date for the SW skeleton in Grave 52 ranges 2560–2202 BC, and the individual in Grave 53 yielded a date of 2872–2476 BC.

The analysed subject from Dösemarken yielded a radiocarbon date of 2472–2210 BC, whereas the date for the individual from Norra Hyllievång ranges 2875–2581 BC. The Svågertorp individual dates to 2579–2349 BC. Unfortunately, no radiocarbon date could be obtained for the analysed individual from Kastanjegården due to a low collagen yield. The child burial at Skepparslöv yielded a radiocarbon date of 2861–2487 BC, and the date for the Åraslöv subject ranges 2621–2350 BC. From Håslöv, the individual buried in Grave 26 has been radiocarbon dated by Torbjörn Ahlström (2009:172) to 2866–2467 BC.

Stable isotope results

The results of the stable isotope analyses are presented in Table 1. The $\delta^{13}C$ values for the analysed samples range from –22.1 to –18.6‰ (mean –20.4 ± 0.8‰, n=59), where the lowest value derives from a long bone from Skepparslöv. Values higher than –19‰ are represented in samples from Norra Hyllievång, Åraslöv and Håslöv. The $\delta^{15}N$ values range between 8.3 and 12.8‰ (mean 10.1 ± 1.1‰, n=59). The three highest obtained values, all above 12‰, derive from the adult individual buried at Åraslöv. Further, two deciduous molars, from Skepparslöv and the child burial in grave 47 at Bedinge, also display $\delta^{15}N$ values of 12‰ or higher, probably representing elevated values as a result of breastfeeding. The 31 obtained $\delta^{34}S$ values range between 8.2 and 15.3‰ (mean 11.6 ± 1.3‰).

Reconstructing dietary patterns

When reconstructing prehistoric dietary patterns from stable isotopes, the ideal scenario includes using local faunal reference samples of approximately the same date as the analysed humans in order to establish local isotope baseline data. However, faunal Scanian Neo-

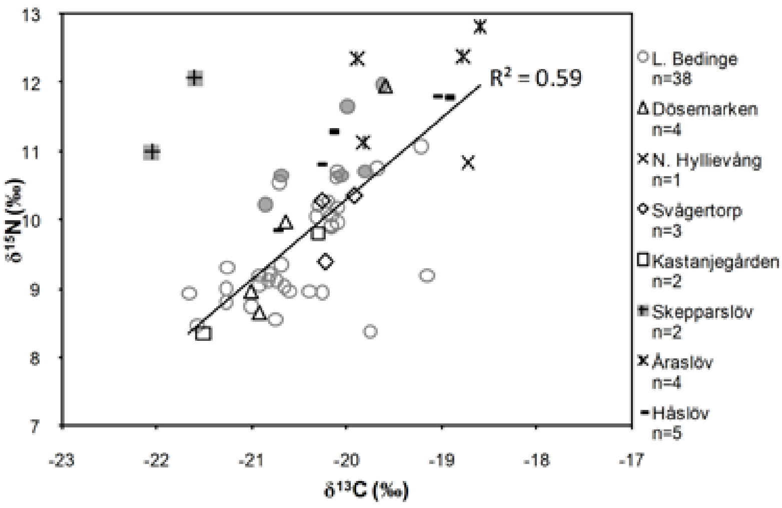

Figure 3. Graph of $\delta^{13}C$ and $\delta^{15}N$ values for all analysed samples. The regression line (R^2=0.59) is calculated with the exclusion of samples where elevated $\delta^{15}N$ values may be the result of breastfeeding (Infant A and Infant B together with deciduous teeth and M_1 from the Child burial in Grave 47 at Lilla Bedinge, and the two samples from Skepparslöv. These datapoints are shaded).

lithic assemblages have not been available for analyses in the present study. An indication of the $\delta^{13}C$ range for terrestrial food sources can be obtained from published data on fauna from the Mesolithic site Ageröd in central Scania (Lidén et al. 2004). Here, $\delta^{13}C$ values from terrestrial herbivores (elk, aurochs, roe deer and red deer) average –22.6 ± 0.4‰ (n=10). It should be emphasised, however, that potential temporal variations in local terrestrial $\delta^{13}C$ values might result in slightly different ranges during MN B compared to the Mesolithic period. Due to temporal fluctuations in salinity in the estuarine Baltic Sea during prehistoric times, marine reference samples from the Mesolithic are unsuitable for comparison with Neolithic conditions. However, an extensive dataset on Neolithic marine fauna recovered on the island of Öland is available (Eriksson et al. 2008), where $\delta^{13}C$ values average –15.1 ± 1.6‰ (n=30). The $\delta^{13}C$ value is enriched by approximately +1‰ for each trophic level (Schoeninger & DeNiro 1984), indicating that a strictly terrestrial human diet would result in a value around –22 to –21‰ in the analysed human samples. Correspondingly, an exclusively marine diet would yield values higher than about –16‰. Further, the Baltic Sea displays somewhat more negative $\delta^{13}C$ values than the oceans due to its inflow of freshwater, and thus marine food sources deriving from waters west of Scania can potentially display even higher values.

Examples of southern Scandinavian populations with isotope values representing homogenous terrestrial diets are found from a Neolithic passage grave at Rössberga in Västergötland (Lidén 1995; Linderholm et al. 2008), and from individuals dated to the Bronze Age interred in a passage grave at Resmo on the island of Öland (Eriksson et al. 2008). The $\delta^{13}C$ values for the Rössberga individuals range between –21.2 and –20.1‰ (mean –20.9 ± 0.5‰, n=30), with $\delta^{15}N$ values of 7.4–9.9‰ (mean 9.3 ± 0.5‰). The Bronze Age individuals from Resmo have $\delta^{13}C$ values between –20.9 and –19.4‰ (mean –20.0 ± 0.4‰, n=31) and $\delta^{15}N$ values ranging 8.8–10.6‰ (mean 9.9 ± 0.5‰). Both populations thus display narrower ranges in both carbon and nitrogen isotopes than the Scanian individuals analysed here. Further, the analysed Scanian samples include higher $\delta^{13}C$ and $\delta^{15}N$ values not represented in Rössberga or Bronze Age Resmo, implying a more varied diet with some contribution of marine protein in several samples.

This suggested contribution of marine resources in the diet for some of the analysed individuals is further supported when analysing the correlation between carbon and nitrogen isotope values in the samples (Fig. 3). Since marine and lacustrine food chains are longer than their terrestrial counterparts, fish and marine mammals will display higher $\delta^{15}N$ values than terrestrial animals. If excluding samples where elevated nitrogen isotope values could be the result of breastfeeding (representing Infant A, Infant B as well as deciduous teeth and M_1 from the Child burial at Lilla Bedinge, and the two samples from Skepparslöv), a

Table 2. Isotope ranges and mean values (± 1 s.d.) for all samples, Lilla Bedinge, SW Scania and NE Scania, respectively.

	$\delta^{13}C$ & $\delta^{15}N$ n	$\delta^{13}C$ mean (‰)	$\delta^{13}C$ range (‰)	$\delta^{15}N$ mean (‰)	$\delta^{15}N$ range (‰)	$\delta^{34}S$ n	$\delta^{34}S$ mean (‰)	$\delta^{34}S$ range (‰)
All samples	59	–20.4 ± 0.8	–22.1 – –18.6	10.1 ± 1.1	8.3 – 12.8	31	11.6 ± 1.3	8.2 – 15.3
Lilla Bedinge	38	–20.5 ± 0.6	–21.7 – –19.1	9.8 ± 0.9	8.4 – 12.0	19	11.6 ± 0.7	10.7 – 12.8
SW Scania	10	–20.3 ± 0.8	–21.5 – –18.7	9.8 ± 1.1	8.3 – 11.9	2	-	10.2 – 10.8
NE Scania	11	–20.0 ± 1.1	–22.1 – –18.6	11.6 ± 0.9	9.8 – 12.8	10	11.8 ± 2.1	8.2 –15.3

linear regression analysis reveals a weak correlation between $\delta^{13}C$ and $\delta^{15}N$ (R^2=0.59). The two samples most evidently deviating from the regression line originate from craniums 2 and 4 in Grave 47 at Lilla Bedinge, and if excluding these samples as well, the correlation between carbon and nitrogen isotopes is even stronger (R^2=0.73). This implies that at least the majority of the variations in the isotopic values can be explained in terms of different proportions of marine protein in the diet. It should be noted that terrestrial animals in coastal regions have occasionally been shown to exhibit $\delta^{13}C$ values indicative of a marine diet. In modern sheep from Orkney, foddering with seaweed has resulted in such high values (Barrett et al. 2000), and grazing on seaweed has been suggested to be a plausible explanation for correspondingly high values in a red deer sample from an Iron Age context on the Scottish Western Isles (Mulville et al. 2009). However, in the present case the general correlation between $\delta^{13}C$ and $\delta^{15}N$ suggest that, at least in the majority of the samples, higher $\delta^{13}C$ values correspond to consumption of foods originating from higher trophic levels and thus rather represent marine fish and/or mammals. Although there are no reference data from Scanian MN B sheep or goats, one can hypothetically assume that their nitrogen isotope values would be lower than marine animals due to their herbivorous nature. The evidently varied diet among the analysed samples thus seems to range from a more or less exclusively terrestrial protein intake to a possibly rather even mixture of marine fish/mammals and terrestrial protein sources. Such mixed diets, with corresponding isotope values, have previously been identified among individuals dated to MN A and MN B interred in a passage grave at Resmo and in MN B individuals from stone cist contexts at Torsborg on Öland (Eriksson et al. 2008). It should be noted, however, that the majority of the samples represent diets with no or only limited contribution of marine food sources. The most substantial proportions of marine dietary protein are found among the samples from Åraslöv, Norra Hyllievång and Håslöv, followed by a few samples from Lilla Bedinge and one from Dösemarken.

The $\delta^{15}N$ values for samples with terrestrial carbon isotope signatures indicate a mainly meat based protein intake. However, the spread along the regression line, most notable among the samples from Lilla Bedinge, might result from terrestrial and/or marine dietary protein deriving from slightly different trophic levels. These variations could imply varying contributions of, for example, vegetarian products, suckling animals or freshwater fish. Marine food sources might include varied proportions of different fish and/or mammal species.

Dietary variations and geography

When comparing dietary data from the three represented geographic regions (Table 2, Fig. 3) the SW Scanian sites, as well as Lilla Bedinge in south Scania, display more or less overlapping carbon and nitrogen isotope values. With a few exceptions, these individuals have included no or limited amounts of marine protein to their diets. The NE Scanian sites, on the other hand, have higher mean values for both $\delta^{13}C$ and $\delta^{15}N$ compared to the SW region and Lilla Bedinge. The samples from Håslöv and Åraslöv, with one exception, display isotope values in line with mixed diets including moderate to substantial proportions of marine protein. In contrast, the two lowest carbon isotope values from the NE region represent the child from Skepparslöv, who has evidently been nursed by a mother exploiting more or less exclusively terrestrial resources.

Among the three sites from NE Scania, Skepparslöv represents the longest distance to the coast, suggesting that geographic location might have played some part in the dietary strategies. During the Middle Neolithic, Åraslöv and Håslöv were both localised close to an inlet connected to the Baltic Sea just south of present day Kristianstad, so marine resources were probably close at hand. However, no such pattern is evident from SW Scania or Lilla Bedinge, although the highest $\delta^{13}C$ value from the SW region represents Norra Hyllievång, located closer to the coast than Kastanjegården and Svågertorp where values are somewhat lower. The

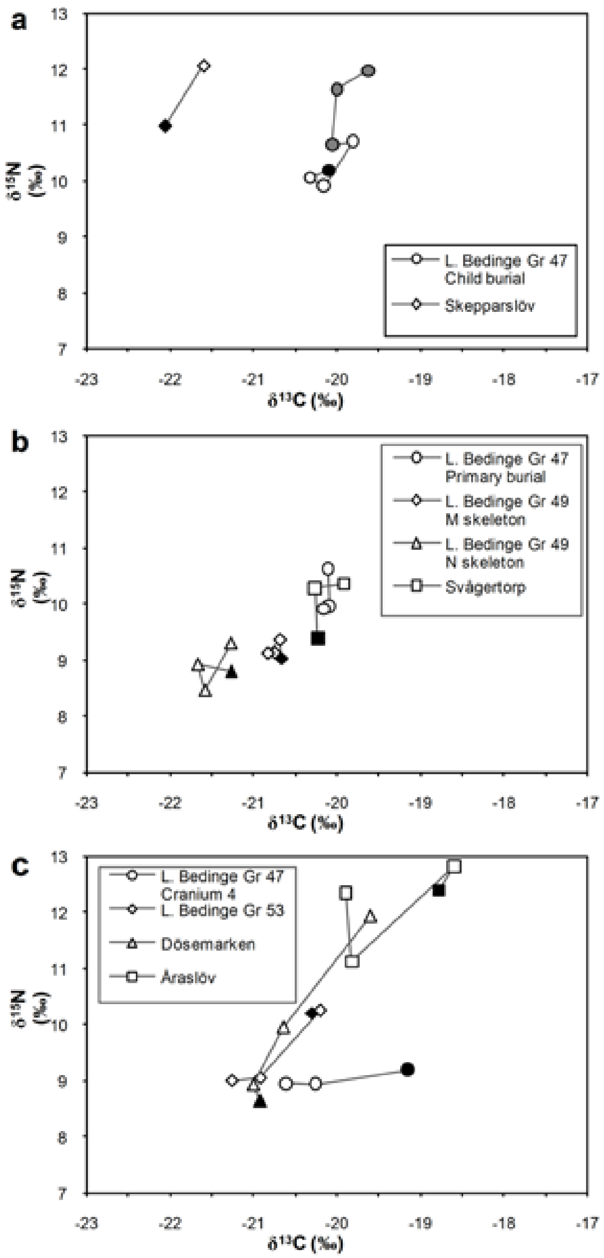

Figure 4. Examples of intra-individual dietary data showing (a) elevated δ^{15}N values connected to breastfeeding, (b) limited intra-individual variations, and (c) moderate intra-individual dietary variations. Grey symbols = deciduous teeth, white symbols = permanent molars, black symbols = bone elements.

Dösemarken individual displays lower values than the Norra Hyllievång sample despite the closer proximity to the coast. Further, the majority of the Lilla Bedinge individuals seem to have exploited no or limited amounts of marine resources despite the sites' location only c. 1 km from the coastline. In conclusion, geographic proximity to the coast may account for some, albeit far from all, of the observed dietary variations. Further, as will be discussed below, we cannot assume that all analysed individuals are actually of local origin.

Dietary life histories

For 15 individuals, dietary data from more than one element are available, enabling investigation of intra-individual dietary patterns. No pronounced dietary changes are implied, although a number of individuals have experienced moderate dietary variations during the course of life. Figure 4 illustrates some examples of individuals displaying moderate and limited intra-individual variations, respectively, and of children with elevated values related to nursing.

Moderate intra-individual changes can be discerned for Cranium 4 in Grave 47 and the individual in Grave 53 at Lilla Bedinge, both displaying values indicative of slightly increased consumption of marine food sources from childhood to later years in life. For the SW skeleton in Grave 52, an observed difference in the δ^{13}C and δ^{15}N values between mandible and femur might suggest a dietary shift occurring at a later stage in life, where the two bone elements might represent different collagen turnover times. Moderate variations in terms of changing proportions of marine dietary protein are further implied for the individuals from Kastanjegården, Åraslöv and Grave 26 in Håslöv. The Dösemarken individual displays a gradual intra-individual decrease in δ^{15}N of a magnitude representing an entire trophic level.

Deciduous teeth and the first molar from the Child burial in Grave 47 display elevated values as a result of nursing, whereas samples representing later stages in life are lower and represent the individuals' post-weaning diet. Further, the child from Skepparslöv displays a lower δ^{15}N value in the long bone compared to dm_1, although both values are elevated compared to the analysed population as a whole. Since bone collagen is continuously remodelled and in this case still exhibits a rather high δ^{15}N value, this could indicate that weaning ended at a later stage in life, or continued up until death. More homogenous intra-individual data are represented in the samples from the Primary burial and Cranium 2 in Grave 47, as well as from the three individuals in Grave 49 from Lilla Bedinge, together with the Svågertorp individual.

Interpreting the sulphur isotope data

Unfortunately, there are no available reference values from local wild fauna that can be used for establishing the local δ^{34}S range. Such a material would have facilitated and strengthened interpretations about residence

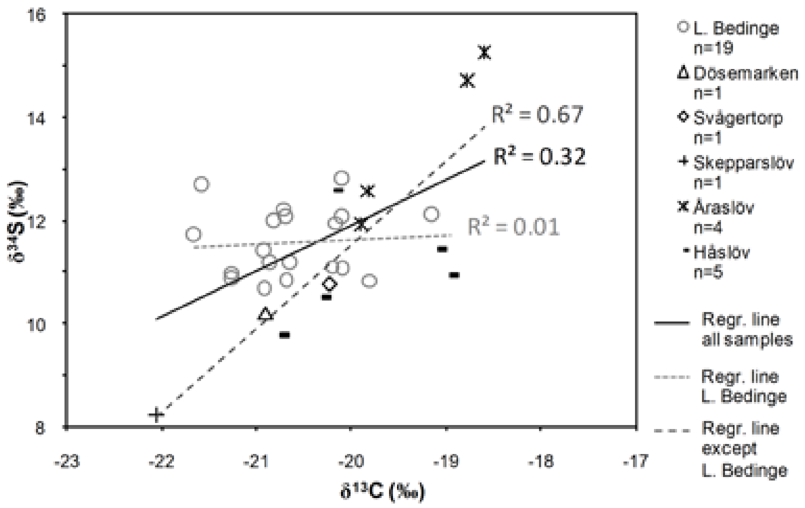

Figure 5. Graph of $\delta^{13}C$ and $\delta^{34}S$ values for all analysed samples. The three regression lines are calculated from the sum of all samples, the Lilla Bedinge samples, and all samples with the exception of Lilla Bedinge, respectively.

and mobility among the analysed human population, although a number of inferences can still be made. The obtained $\delta^{34}S$ values, presented in Fig. 5, include a few obvious outliers among a bulk of moderately varied values. In order to properly interpret the data, however, we need to take the observed dietary variations into consideration. To what extent can the differences in sulphur isotope values be explained in terms of different proportions of consumed marine food sources? The southern Baltic Sea $\delta^{34}S$ signature during the Neolithic has been established from analysis of marine fauna recovered on Öland (Linderholm et al. ms.), where values range 13.6–17.3‰ (mean 15.1 ± 1.1, n=8). Further, marine food sources from waters west of Scania are likely to exhibit even higher values since ocean water sulphate in this environment will be less influenced by freshwater inflow. Elevated $\delta^{34}S$ values corresponding to high $\delta^{13}C$ signatures in the analysed samples can thus potentially be explained in terms of diet rather than non-local origin.

If again employing regression analysis as a tool for studying potential correlation between carbon and sulphur isotope values, the correspondence for the sum of all analysed samples (R^2=0.32) is very low. However, the graph in Fig. 5 implies that this low correspondence can largely be explained by the Lilla Bedinge samples. The R^2 value of 0.01 for the Lilla Bedinge samples shows no correlation whatsoever between the two parameters. The sum of the remaining samples, on the other hand, yield a rather high correspondence (R^2=0.67), implying that the majority of the variations in $\delta^{34}S$ for these samples can be explained in terms of different proportions of marine dietary protein, although there is still some variation along the regression line. This approach, however, is also connected with some problems.

The linear correlation between carbon and sulphur isotopes for the samples from SW and NE Scania can largely be explained by a few outliers; the sample from Skepparslöv with considerably low $\delta^{13}C$ and $\delta^{15}N$ values, and the two Åraslöv samples that display much higher $\delta^{34}S$ values than the remaining samples in combination with high $\delta^{13}C$ values. Samples with $\delta^{13}C$ values around –21‰ are not likely to be influenced by marine protein. Hence, the lower $\delta^{34}S$ value for the Skepparslöv sample compared to, for example, the values from Grave III at Håslöv, is unlikely to be the result of higher amounts of (local) terrestrial protein. Further, the Skepparslöv site is located on the border zone between Precambrian crystalline rocks and the Cretaceous limestone formation. A more or less local diet for this subject might thus include food sources from a region with a potentially different sulphur isotope ecology than what has been prevalent at Håslöv and Åraslöv. It should be noted however, that the sharp geological boundaries are not directly reflected in the bioavailable sulphur isotope signatures, since glacial and postglacial processes of sediment transportation tend to even out these marked delimitations.

The two deviating values from the Åraslöv individual would, if interpretations were strictly based on the regression analysis, correspond to a high intake of marine protein rather than a non-local origin. However, these values are as high as those reported for Neolithic Baltic Sea marine fauna. Further, the values are higher than a majority of the values previously obtained from a Middle Neolithic human population of marine consumers

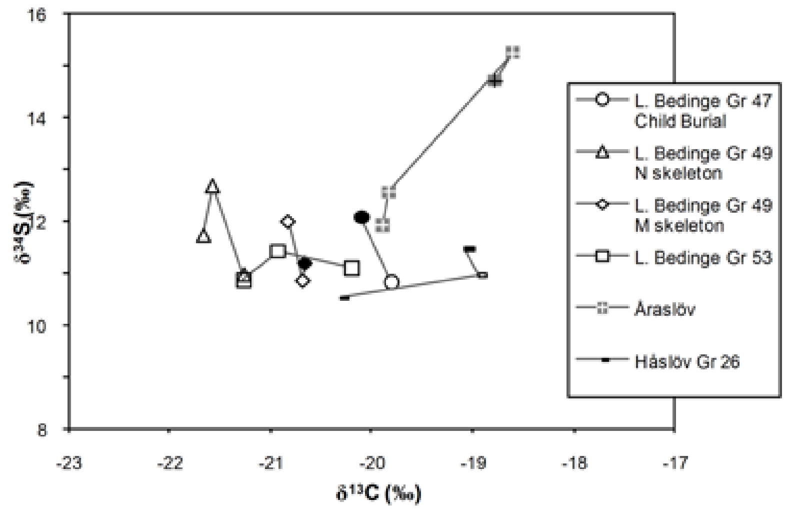

Figure 6. Intra-individual δ^{13}C and δ^{34}S data. White symbols = permanent molars, black symbols = bone elements.

buried at Köpingsvik on Öland (Linderholm et al. ms.), where δ^{34}S values average 12.5 ± 2.2‰ (n=27). Since the carbon isotope data for the two Åraslöv samples indicate intake of both marine and terrestrial dietary protein, δ^{34}S values are expected, if resulting from a mixture of local terrestrial and marine food sources, to be lower than those reported. In light of the marine faunal reference data from Öland, the sulphur isotope signature of the consumed terrestrial food sources for the deviating Åraslöv samples rather seem to be about as high as values in the Baltic Sea. Such high values clearly stands out from the bulk of the samples analysed here, including those from Håslöv and the remaining two Åraslöv samples, indicating that the values represent a non-local origin.

The remainder of the samples from NE and SW Scania display δ^{34}S values which roughly correlate with the variation in carbon isotope values, indicating that local origins are quite possible. However, the data also implies that the two regions exhibit similar local terrestrial isotope signatures, allowing for the possibility that these samples represent origins from large parts of Scania, or indeed from other geographical regions with similar local δ^{34}S values.

As noted above, the pattern among the Lilla Bedinge samples is somewhat different, since there is no general correlation between the carbon and sulphur isotopes. The δ^{34}S data, with a mean of 11.6 ± 0.7‰ (n=19), imply that the samples represent predominantly, and possibly exclusively, local individuals. However, in samples displaying δ^{13}C values of around –20‰ or higher, indicating limited proportions of marine food sources contributing to the diet, there is no apparent correlation between carbon and sulphur isotopes. This could indicate that the population is somewhat heterogeneous in terms of geographic origins, but these indices are too vague to warrant any certain conclusions. The δ^{34}S values for samples with clearly terrestrial dietary signals may imply that local terrestrial sulphur at Lilla Bedinge has a somewhat higher, and possibly more varied, δ^{34}S signature than in SW and NE Scania. The range in δ^{34}S values could result from variation on a more local level, although it is also possible that it represents some altogether different geographic origins among the analysed individuals. Again, the results are inconclusive.

Life histories in terms of mobility

Additional insights into mobility and residence patterns can potentially be obtained from the study of intra-individual δ^{34}S data. Stable sulphur isotope data from more than one element is available for six subjects; four from Lilla Bedinge together with the individuals from Åraslöv and Grave 26 at Håslöv (Fig. 6). In light of the above discussion of the Åraslöv samples, this individual seem to have experienced a change in residence somewhere between childhood and early teenage years, with a corresponding dietary shift towards a utilisation of a higher proportion of marine resources. This individual may have spent the childhood close to Åraslöv, or in a region with a similar local sulphur isotope signature, but the values representing a later stage in life are clearly non-local. There are no indications of residential change for the individuals from Grave 26 at Håslöv or Grave 53 at Lilla Bedinge, where the shifts in $\delta^{34}S$ for the Håslöv individual seem to correlate with the changing proportions of marine dietary protein. Data for the remaining three Lilla Bedinge individuals, however, are less clear cut. All exhibit shifts in $\delta^{34}S$, not correlating with $\delta^{13}C$ changes, exceeding 1‰. Such minor changes could potentially be the result of variations in $\delta^{34}S$ on the local level, although the shift of 1.7‰ between M_1 and M_2 for the North skeleton in Grave 49 seems to indicate residential change. For the Middle skeleton in Grave 49 and the Child burial in Grave 47, however, values can be considered inconclusive regarding potential changes in residence.

MN B mobility in a southern Swedish perspective

If comparing with sulphur isotope data on MN B individuals from Resmo (Linderholm et al. ms.), there is a higher degree of clearly non-local as well as mobile individuals on Öland compared to the Scanian communities. A similar tendency of high mobility on Öland is further discerned in strontium isotope data (Fornander et al. ms.). Among the Öland individuals, there are even indications of several changes in residence taking place during the course of life, implying a different pattern than what is observed in Scania. It should be noted, that the Öland material was not recovered from a BAC context. The fact that several foreign and travelling individuals have been interred in an older megalith monument on the island is in itself a highly interesting observation, especially when compared to the more localised Scanian communities implied here.

Some concluding remarks

The general notion of a farming/pastoralist economy of the Battle Axe Culture clearly needs some revision. Although the majority of the analysed Scanian individuals seem to have utilised primarily terrestrial food sources, there is an evident diversity in the dietary patterns, also reflected among MN B individuals from the island of Öland. The relatively close proximity to the coast in these two regions seems to have promoted the inclusion of marine resources in the food culture of at least some members of these MN B communities.

With a few exceptions, the analysed individuals seem to represent members of the local MN B communities in Scania, and movements between different parts of this region are plausible in a few cases. The extensive contact networks which seem to be implied in the conventionality of Battle Axe Culture burials and associated artefacts on a wider regional level are thus not reflected in the analysed Scanian material. Further, the indications of people travelling far and wide among the MN B individuals on Öland are not mirrored in the Scanian material.

From a methodological perspective, this study elucidates how conclusions about mobility and provenience are closely connected to insights into, and comparison with, the observed dietary patterns in terms of contributing marine resources. When dealing with populations in regions close to the coast, isotopic dietary data is thus essential for drawing valid conclusions about prehistoric mobility patterns. Further, if applying a portion of self criticism, faunal reference values indicating the local sulphur isotope ecology will certainly facilitate the interpretations of human isotope values, leading to more legitimate conclusions about residence and mobility.

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References

Ahlström, T. 2009. *Underjordiska dödsriken*. Department of Archaeology, Göteborg.

Ambrose, S. H. 1990. Preparation and Characterization of Bone and Tooth Collagen for Isotopic Analysis. *Journal of Archaeological Science* 17, pp. 431–451.

Ambrose, S. H. & Norr, L. 1993. Experimental Evidence for the Relationship of the Carbon Isotope Ratios of Whole Diet and Dietary Protein to Those of Bone Collagen and Carbonate. Lambert, J. D. & Grupe, G. (eds.): *Prehistoric Human Bone: Archaeology at the Molecular Level,* pp. 1–37. Berlin.

Barrett, J. H., Beukens, R. P. & Brothwell, D. R. 2000. Radiocarbon dating and marine reservoir correction of Viking Age Christian burials from Orkney. *Antiquity* 74, pp. 537–543.

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

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

DeNiro, M. J. & Epstein, S. 1978. Carbon Isotopic Evidence for Different Feeding Patterns in Two Hyrax Species Occupying the Same Habitat. *Science* 201, pp. 906–908.

During, E. 1989. En osteologisk och antropologisk undersökning av tre skelettgravar från Bedingegravfältet. Larsson, L. (ed.): *Stridsyxekultur i Sydskandinavien. Rapport från det andra nordiska symposiet om stridsyxetid i Sydskandinavien, 31.X – 2.XI 1988.* Department of Archaeology, Lund.

Eriksson, G. 2003. *Norm and difference. Stone Age dietary practice in the Baltic region.* Archaeological Research Laboratory, Stockholm.

Eriksson, G., Linderholm, A., Fornander, E., Kanstrup, M., Schoultz, P., Olofsson, H. & Lidén, K. 2008. Same island, different diet: Cultural evolution of food practice on Öland, Sweden, from the Mesolithic to the Roman Period. *Journal of Anthropological Archaeology* 27, pp. 520–543.

Faure, G. & Mensing, T. M. 2005. *Principles of Isotope Geology*. New York.

Fogel, M. L., Tuross, N. & Owsley, D. W. 1989. Nitrogen Isotope Tracers of Human Lactation in Modern and Archaeological Populations. *Annual Report from the Director of the Geophysical Research Laboratory at the Carnegie Institution of Washington 1988–1989,* pp. 111–117. Washington.

Fornander, E., Eriksson, G. & Lidén, K. 2008. Wild at Heart: approaching Pitted Ware identity, economy and cosmology through stable isotopes in skeletal material from the Neolithic site Korsnäs in Eastern Central Sweden. *Journal of Anthropological Archaeology* 27, pp. 281–297.

Fornander, E., Lidén, K. & Andersson, P. ms. Identifying mobility in populations with mixed marine-terrestrial diets: strontium isotope analysis of skeletal material from a passage grave in Resmo, Öland, Sweden. Manuscript.

Forssander, J.-E. 1932. Från hällkisttid och äldre bronsålder i Skåne. *Meddelanden från Lunds universitets historiska museum* 1931–32, pp. 218–234.

Forssander, J.-E. 1933. *Die Schwedische Bootaxtkultur und ihre Kontinentaleuropäischen Voraussetzungen.* Lund.

Forssander, J.-E. 1934. Zur Kenntnis der Spätneolithischen Streitaxtkulturen in Mittel- und Nordeuropa. *Meddelanden från Lunds universitets historiska museum* 1933–34, pp. 227–270.

von Hackwitz, K. 2009. *Längs med Hjälmarens stränder och förbi – relationen mellan den gropkeramiska kulturen och båtyxekulturen.* Department of Archaeology and Classical Studies, Stockholm.

Hansen, F. 1934. Gravundersökningar i sydligaste Skåne. *Meddelanden från Lunds universitets historiska museum* 1933–1934, pp. 270–275.

Hedges, R. E. M., Clement, J. G., Thomas, C. D. L. & O'Connel, T. C. 2007. Collagen turnover in the adult femoral mid-shaft: modelled from anthropogenic radiocarbon tracer measurements. *American Journal of Physical Anthropology* 133, pp. 808–816.

Ifverson, P. 2007. *Dösemarken fastigheten Limhamn 155:355: Hyllie socken i Malmö stad, Skåne län: arkeologisk förundersökning 2006.* Malmö.

Jantsch, A. K. & Ranåker, M. 2001. Stridsyxekulturen. En humanosteologisk studie i en bioarkeologisk kontext: analys av tillväxt och paleopatologi. Unpublished seminar report, Department of Archaeology, Lund.

Koch, H.& Tuominen, K. 2006. *Svågertorps industriområde delområde K, P & S: Bunkeflo socken i Malmö stad, Skåne län: arkeologisk slutundersökning 2000.* Malmö.

Knutsson, K. 1995. *Slutvandrat? Aspekter på övergången från rörlig till bofast tillvaro.* Department of Archaeology, Uppsala.

Larsson, Å. M. 2009. *Breaking and making bodies and pots: material and ritual practices in Sweden in the third millennium BC.* Department of Archaeology and Ancient History, Uppsala.

Lidén, K. 1995. Megaliths, agriculture and social complexity. A diet study of two Swedish megalith populations. *Journal of Anthropological Archaeology* 14, pp. 404–417.

Lidén, K. & Angerbjörn, A. 1999. Dietary change and stable isotopes: A model of growth and dormancy in cave bears. *Proceedings of the Royal Society of London: Series B* 266, pp. 1779–1783.

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, pp. 23–33.

Lidén, K., Nelson, E. D. 1994. Stable carbon isotopes as dietary indicator, in the Baltic area. *Fornvännen* 89, pp. 13–21.

Linderholm, A., Fornander, E., Eriksson, G., Mörth, C. M. & Lidén, K. ms. Increasing mobility at the Neolithic/Bronze Age transition – sulphur isotope evidence from Öland, Sweden. Manuscript.

Linderholm, A., Mörth, C. M., Richards, M. & Lidén, K. 2008. A Case Study of Stable Isotopes ($\delta^{13}C$, $\delta^{15}N$, $\delta^{34}S$) on Human and Animal Bones from the Passage Tomb at Rössberga in Cental Sweden. Linderholm, A. *Migration in Prehistory. DNA and Stable Isotope Analyses of Swedish Skeletal Material.* Archaeological Research Laboratory, Stockholm.

Lindhé, E. & Grehn, F. 2008. *Norra Hyllievång Hyllie socken i Malmö stad, Skåne län: arkeologisk slutundersökning 2006.* Malmö.

Loberg, B. 1999. *Geologi. Material, processer och Sveriges berggrund.* Stockholm.

Malmer, M. P. 1962. *Jungneolithische Studien.* Lund.

Malmer, M. P. 1975. *Stridsyxekulturen i Sverige och Norge.* Lund.

Malmer, M. P. 2002. *The Neolithic of south Sweden: TRB, GRK and STR.* Stockholm.

Minagawa, M. & Wada, E. 1984. Stepwise enrichment of ^{15}N along food chains: further evidence and the relation between $\delta^{15}N$ and animal age. *Geochimica et Cosmochimica Acta* 48, pp. 1135–1140.

Mulville, J., Madgwick, R., Stevens, R., O'Connell, T., Craig, O., Powell, A., Sharples, N. & Parker Pearson, M. 2009. Isotopic Analysis of Faunal Material from South Uist, Western Isles, Scotland. *Journal of the North Atlantic* 2, pp. 51–59.

Peterson, R. W. & Fry, B. 1987. Stable isotopes in ecosystem studies. *Annual Review of Ecology and Systematics* 18, pp. 293–320.

Peterson, B. J., Howarth, R. W. & Garritt, R. H. 1985. Multiple Stable Isotopes Used to Trace the Flow of Organic Matter in Estuarine Food Webs. *Science* 227, pp. 1361–1363.

Rees, C. E., Jenkins, W. J. & Monster, J. 1978. The sulphur isotopic composition of ocean water sulphate. *Geochimica et Cosmochimica Acta* 42, pp. 377–381.

Richards, M. P., Fuller, B. T., Sponheimer, M., Robinson, T. & Ayliffe, L. 2003a. Sulphur isotopes in palaeodietary studies: a review and results from a controlled feeding experiment. *International Journal of Osteoarchaeology* 13, pp. 37–45.

Richards, M. P., Schulting, R. J. & Hedges, R. E. M. 2003b. Sharp shift in diet at onset of the Neolithic. *Nature* 425, p. 366.

Rowley-Conwy, P. 2004. How the West was lost: A reconsideration of agricultural origins in Britain, Ireland and Southern Scandinavia. *Current Anthropology* 45, Supplement.

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, pp. 625–639.

Sealy, J., Armstrong, R. & Schrire, C. 1995. Beyond lifetime averages: tracing life histories through isotopic analysis of different calcified tissues from archaeological human remains. *Antiquity* 69, pp. 290–300.

Welinder, S. 1998. Del 1. Neoliticum–bronsålder, 3900–500 f.Kr. Welinder, S., Pedersen, E. A. & Widgren, M. (eds.): *Jordbrukets första femtusen år. 4000 f.Kr.–1000 e.Kr.* Stockholm.

Whittle, A. & Cummings, V. (eds.) 2007. *Going Over: The Mesolithic–Neolithic Transition in North-West Europe*. Oxford.

Winge, G. 1976. *Gravfältet vid Kastanjegården.* Malmö.

Unpublished sources

During, E. Unpublished notes from 1992 on osteological analysis of Grave 49 at Lilla Bedinge. Currently reposited at the Osteoarchaeological Research Laboratory, Stockholm University.