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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

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ABSTRACT

The Middle Neolithic Pitted Ware Culture on the Baltic Sea islands comprised a common identity distinguished, in part, by an almost exclusively marine diet. Based on evidence from the first stable isotope analysis on Pitted Ware skeletal material from the Eastern Central Swedish mainland, we suggest that this identity was shared by PWC groups in the archipelago of the west side of the Baltic. Fifty-six faunal and 26 human bone and dentine samples originating from the Pitted Ware site Korsnäs in Södermanland, Sweden were analysed, and the data clearly shows that the diet of the Korsnäs people was marine, predominantly based on seal. The isotope data further indicate that the pig bones found in large quantities on the site emanate from wild boar rather than domestic pigs. The large representation of pig on several Pitted Ware sites, which cannot be explained in terms of economy, is interpreted as the results of occasional hunting of and ritual feasting on wild boar, indicating that the animal held a prominent position, alongside seal, in the hunting identity and cosmology of the Pitted Ware people. Further, eleven new radiocarbon dates are presented, placing the Korsnäs site, with a large probability, within Middle Neolithic A.

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Introduction

The Early and Middle Neolithic in southern and central Scandinavia is marked by an intriguing complexity concerning material culture, site location and adoption of Neolithic ideals. While the concepts of agriculture and pastoralism were incorporated into the economy and cosmology of people living in the interior parts of the area, groups of hunter–fisher–gatherers, traditionally referred to as the Pitted Ware Culture (PWC), occupied and utilized the coast. These PWC groups display considerable regional variation, implying that the “culture” must be understood as a set of differing ideals with a few common features, where a mentality emphasising the coast and the sea is a focal point.

The eastern part of the PWC area, including the Eastern Central Sweden archipelago and the Baltic islands Öland, Gotland and Åland, has been referred to as the classical area for the PWC (Nygård, 1989; Wyszomirska, 1984), with a maritime hunting mentality where the seal have been of great economic and ideological importance (Stenbäck, 1998; Stenbäck, 2003; Storå, 2001; Österholm, 1989). However, the nature and economy of the PWC in this region has been debated. It has been suggested that the Pitted

Ware people, in addition to hunter–fisher–gatherer activities, also engaged in pig herding (Burenhult, 1999; Hedemark et al., 2000; Jonsson, 1986; Lindqvist and Possnert, 1997; Wallin and Martinsson-Wallin, 1992; Welinder et al., 1998; Österholm, 1989) or occasional plant cultivation (Carlsson, 1987; Carlsson, 1998; Gill, 2003; Stenbäck, 2003). Other researchers have argued that differences in material culture during the Middle Neolithic represent different aspects of the same groups of people rather than separate cultures or ethnic groups (Andersson, 1998; Carlsson, 1991; Carlsson, 1998; Edén et al., 1997). Werbart (2007) questions the concepts of the Scandinavian Neolithic “cultures”, arguing in favour of an increased focus on interactions and relations across the Baltic when approaching the so called “Pitted Ware Culture” (for reviews of previous PWC research, see Lidén and Eriksson, 2007; Pappmehl-Dufay, 2006).

In addition to the ideological emphasis of the seal among PWC groups, the pig seems to have been assigned specific symbolic meanings. Pig bones and tusks are frequent in PWC burial contexts on Gotland, as well as in the faunal assemblage on some settlement sites (cf. Österholm, 1989). This large representation of pigs has also been identified on settlement sites in the archipelago of the west side of the Baltic, where PWC burials are rarely found (e.g. Aaris-Sørensen, 1978; Hårding, 1996; Lepiksaar, 1974; Olson, 1994). The questions of whether these pigs were wild or domestic,

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and to what extent, if at all, they were a part of the human diet, have been widely debated.

Previous dietary studies have been performed through stable isotope analysis on PWC skeletal material from the Baltic islands. The results indicate a diet based almost exclusively on marine resources, predominantly seal (Eriksson, 2004; Eriksson et al., 2008; Lidén et al., 1995, 2004). The Baltic PWC sites seem to represent the existence of a distinct group of people where shared conceptions concerning for example food comprised a unifying feature. In this study, we investigate whether this common identity was expressed in the archipelago of the Eastern Central Swedish mainland coast as well. We present results from the first stable isotope analysis on Neolithic skeletal material from this area, and thereby attempt to fill a considerable gap in the knowledge and understanding of the PWC. Questions concerning dietary strategies as well as possible human movements across the Baltic are addressed. The analysed samples all originate from the PWC site Korsnäs on the Södertörn peninsula in Södermanland. The bone material from Korsnäs is rather well preserved, a highly unusual circumstance in a region where sandy, minerogenic soils offer adverse preservation conditions and organic material dating from the Neolithic is rarely found. Further, we attempt to reach an understanding for the nature of the meanings assigned to the pig in PWC contexts, and approach the question of whether or not the pigs found in large quantities on the Korsnäs site were wild or domesticated.

Background

The Neolithic in Central Sweden is chronologically divided into the Early Neolithic (EN, c. 4000–3300 BC), Middle Neolithic A (MN A, c. 3300–2700 BC), Middle Neolithic B (MN B, c. 2700–2300 BC) and Late Neolithic (LN, c. 2300–1800 BC) (Papmehl-Dufay, 2006). The beginning of the Early Neolithic in Eastern Central Sweden displays several signs of structural changes. Finds in the interior parts of the region start to appear, presenting evidence of domestic animals (sheep/goat and possibly pig), ceramics and indications of agricultural activities. Ornamented pottery on these sites can be assigned to the Funnel Beaker Culture (TRB), a wide-spread Northern European culture complex associated with a specific ideology including collective burials in megalithic tombs, although the monumentality aspect does not seem to be embraced in Eastern Central Sweden (Kihlstedt et al., 1997). From the middle of the EN, the coast again becomes a focal point, this time with the emergence of the Pitted Ware Culture, which seems to co-exist with the TRB for a few hundred years (Edenmo et al., 1997).

During MN A, the TRB presence in the region seems to have ceased, although there is a continuity of TRB finds in other parts of Scandinavia within this period. MN B marks the appearance of a new set of artefacts, in addition to the PWC finds. They are assigned to the Battle Axe Culture (BAC, alias Corded Ware Culture), a cultural complex with continental influences, with a parallel in the Danish Single Grave Culture. Battle axes, BAC pottery and sparse occurrences of bones from sheep/goat appear inland, often in a context with individual flat-grave inhumations (Edenmo et al., 1997).

The Pitted Ware Culture appears in a wide area of Scandinavia, including the southern and central parts of Sweden as far north as Dalarna and Hälsingland, northeastern Denmark and eastern Norway, as well as the Baltic islands Gotland, Öland and Åland (Fig. 1). The PWC has traditionally been defined by the presence of three characteristic artefacts: tanged arrowheads, cylindrical cores and pottery decorated with pits. However, these assemblages are not complete everywhere, and there are great differences in the sets of artefacts between different regions. The eastern PWC region

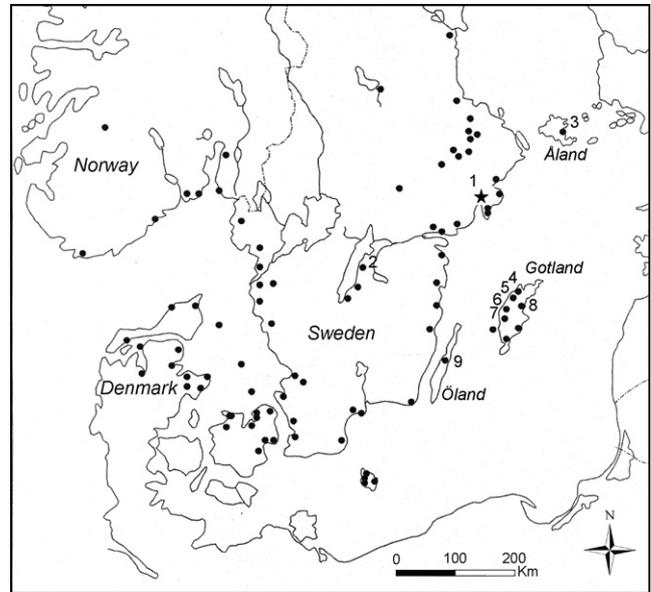


Fig. 1. The distribution of larger Pitted Ware sites in Scandinavia. The Korsnäs site is marked with a star. Numbering refers to sites from which stable carbon and nitrogen isotope data are available. 1—Korsnäs (present study), 2—Alvastra (Sælebakke and Welinder, 1988), 3—Jettböle (Lidén et al., 1995), 4—Ire (Lidén and Nelson, 1994), 5—Grausne (Lidén, 1995), 6—Visby (Lidén, 1995), 7—Ajvide (Lidén, 1995), 8—Västerbjers (Eriksson, 2004), 9—Köpingsvik (Eriksson et al., 2008).

displays large amounts of Pitted Ware pottery, whereas the frequency of flint tools is low, mainly due to the lack of natural occurrences of flint in this region (Edenmo et al., 1997; Nygaard, 1989; Welinder, 1973).

The PWC in this eastern region is further characterized by agglomerations of small groups of coast-bound sites, traditionally interpreted as settlements. The sites often display large amounts of pottery, as well as occurrences of different structures, which mainly consist of pits or diffuse dark coloured features and only rarely are connected with huts or houses. Indications of agriculture on the sites are very rare (Edenmo et al., 1997). The faunal bone material is dominated by seal followed by fish. Pig is represented in varied quantities, and dominates the faunal assemblage on some PWC sites. A few of the sites include human bone material, either scattered throughout the cultural layer or in the form of flat-grave inhumations situated within the settlement area (Edenmo et al., 1997; Stenbäck, 1998).

The Korsnäs site

The Korsnäs site is situated on a southern slope of a ridge in Grödinge parish, on the northwestern part of the Södertörn peninsula in the province of Södermanland. The bedrock in the area consists of granites and gneisses of sedimentary and granitoid origin. Several PWC sites have been identified in close vicinity to Korsnäs (Fig. 2), and the area seems to have been frequently utilised from the Mesolithic onwards (Olsson et al., 1994; Olsson and Kihlstedt, 2000). The extension of the activity area has been estimated through phosphate mapping to ca 95,000 m² (Fig. 3), topographically including levels between ca 18 and 50 m.a.s.l., with a higher frequency of finds in the interval 25–35 m.a.s.l. According to shoreline displacement curves, the sea level during the PWC phase in the region was about 25–30 m higher than today (Olsson et al., 1994; Risberg et al., 1991). During the main period of activity, as indicated by the higher frequency of finds in the area 25–35 m.a.s.l., the Korsnäs site was located on the north-eastern part of a small island, which eventually merged with Södertörn, a larger island sit-

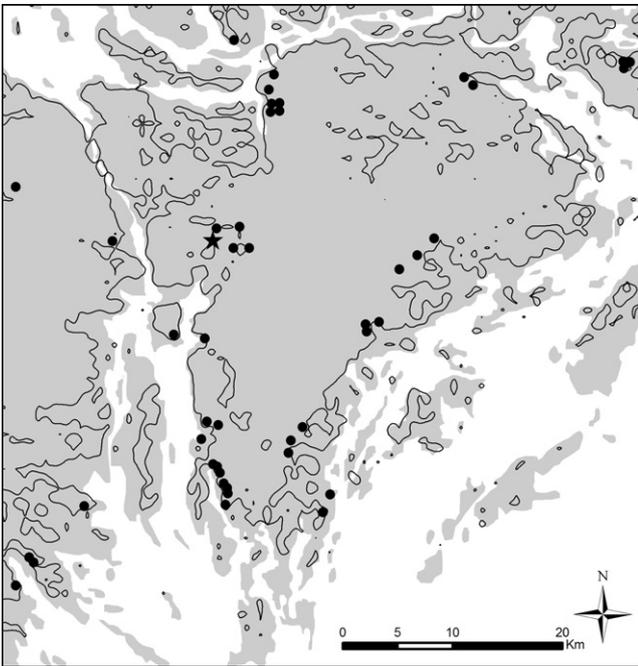


Fig. 2. Map of the present day Södertörn peninsula with the 25 m.a.s.l. elevation curve outlined. PWC sites are marked by filled circles, Korsnäs is marked by a star. The elevation curve is statistically calculated from the National Land Survey of Sweden (LMV) Terrain Elevation Databank data (National Reference System: RH 70).

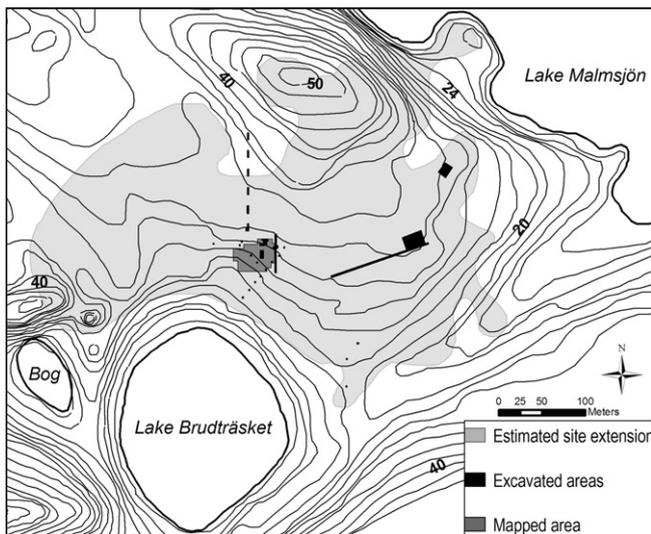


Fig. 3. Map of the estimated extension of, and previous surveys on, the Korsnäs site. Extension area is estimated from phosphate values $>100\text{P}^{\circ}$. Revised after Werthwein (2002).

uated to the east (Fig. 2). In this archipelagic environment, presenting a multitude of both terrestrial and marine food sources, the Korsnäs site was strategically placed on the sandy slope of an inlet (Olsson et al., 1994; Olsson and Kihlstedt, 2000).

The site was discovered and subsequently excavated in the 1930s (ATA¹ 4197/30; 3683/33). In connection with the planning of a gravel quarry in the 1960s, the upper layers of soil were removed from a ca 2000 m² section of the site, damaging the cultural

layer. This was followed by surface collection of exposed finds in 1964, excavation of 136 m² of the damaged area in 1970 (Fig. 4), and partial sieving of the large dump heaps accumulated through the stripping of the soil in 1971–72 (Olsson et al., 1994, ATA 3347/64). In 2002, BAC potsherds as well as a pre-Roman Iron Age grave were recovered in a minor survey ca 100 m south-east of the damaged area (Werthwein, 2002).

The artefacts from Korsnäs mainly consist of pottery and stone tools such as flakes, grinding stones, axes, arrowheads and chisels. Other inorganic artefacts are ceramic figurines and clay beads. The Korsnäs site further presents a number of bone/antler artefacts such as chisels, harpoons, points, anthropomorphic figurines and tooth beads. No traces of building constructions have been found on the site. Identified features are graves, pits and unexcavated hearths (Olsson et al., 1994). It should be noted that Neolithic hearths seem to be absent on PWC sites on Södertörn, and that hearths identified on these sites have been dated to the Iron Age (Olsson, 1996).

Three definite and three possible graves (definite graves are defined as containing seemingly intentional deposits of human skeletal material, (Olsson et al., 1994)), all without any visible constructions, were completely or partially examined during the 1970 excavation (Fig. 4). In addition, human bones were found scattered throughout the cultural layer. This presence of well preserved, unburned human bones on a PWC site is very rare for the Eastern Central Swedish mainland.

Of the c. 17 kg animal bones found in 1970, 98% are unburned, and about 97% of the material consists of mammal species. The mammal bones identified to species are dominated by seal (weight (%) = 36.6, MNI = 12, NISP = 788) and pig (weight (%) = 26.3, MNI = 13, NISP = 417), although a large number of terrestrial faunal species are represented in the material. The seal bones are dominated by specimens of harp seal, but fragments of ringed seal and grey seal have been identified in sparse numbers. Fish comprise 2.8% by weight of the analysed material (Aaris-Sørensen, 1978).

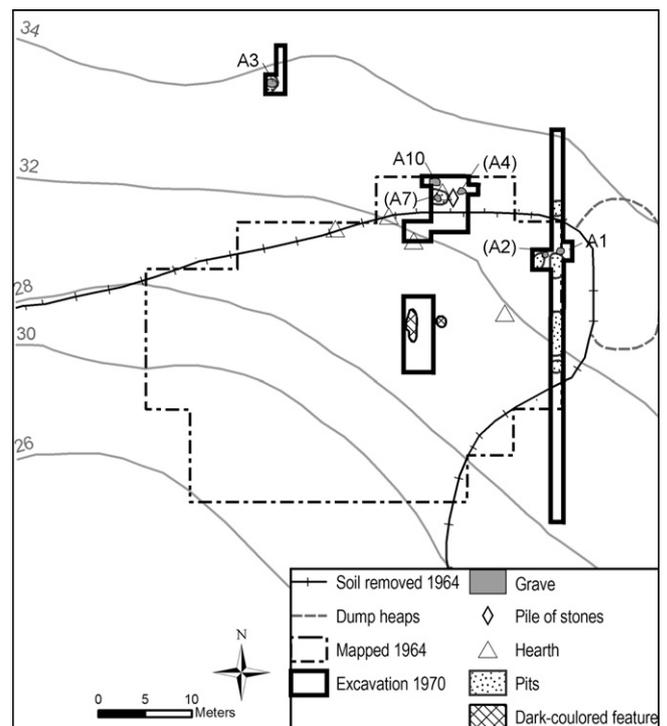


Fig. 4. Map of definite (labeled A) and possible (labeled A) graves, identified during the 1970 survey on Korsnäs. The dark coloured features and some of the hearths were recovered during the 1933 excavation. After Olsson et al. (1994).

¹ Abbreviation: ATA, Antikvarisk-topografiska arkivet (Archives of the National Heritage Board and Museum of National Antiquities).

The location in a contemporary inner archipelago has caused Olsson et al. (1994) to interpret the Korsnäs site as a base camp, probably of a large size or utilised for a long period of time. Based on the faunal assemblage on the site, an economy based on hunting of seal, moose and wild boar together with fishing has been suggested (Aaris-Sørensen, 1978; Olsson et al., 1994). Pollen analyses of sediments from the Korsnäs peat bog, located ca 250 m southwest of the excavation area, show no indications of agricultural activity, and only marginal human impact on the landscape during EN and MN (Miller and Robertsson, 1981). The finds from the Korsnäs site correlate to a large extent with contemporaneous sites in Eastern Central Sweden, although influences from the Comb Ceramic Culture on the Eastern shores of the Baltic can be observed through the presence of curved chisels and secondarily used pottery fragments. These artefacts are very rare in the region, but have been observed in Finland and in PWC contexts on Åland (Olsson et al., 1994).

Methods

Human and faunal bone and tooth dentine collagen samples were subjected to stable carbon, nitrogen and sulphur isotope analysis. Stable isotope ratios of these elements can be applied as proxies for palaeodiet, since their isotopic proportions in body tissue are dependent on the protein component of the diet (Ambrose and Norr, 1993; DeNiro and Epstein, 1978; Schoeninger and DeNiro, 1984). Studies of stable sulphur isotopes can further yield information on geographical origin and migratory patterns (Peterson et al., 1985; Richards et al., 2003). The values $\delta^{13}\text{C}$, $\delta^{15}\text{N}$ and $\delta^{34}\text{S}$ in per mil (‰) express the ratios of $^{13}\text{C}/^{12}\text{C}$, $^{15}\text{N}/^{14}\text{N}$ and $^{34}\text{S}/^{32}\text{S}$ relative to the standards PDB, AIR (atmospheric N_2) and VCDT for carbon, nitrogen and sulphur, respectively. Values are calculated as $((R_{\text{sample}}/R_{\text{standard}}) - 1) \times 1000$, where R is the isotopic ratio. Stable isotope analysis is only applicable on unburnt skeletal material, since heating causes alteration of the isotopic composition (DeNiro, 1985).

Bone collagen is constantly being remodelled during a person's lifetime, with turnover rates ranging between approximately 5 and 30 years, depending on age and bone element (Hedges et al., 2007; Lidén and Angerbjörn, 1999). Isotopic data derived from bone collagen thus represent the average protein intake for an individual during several years prior to death. Tooth dentine, on the other hand, is metabolically inert, and the isotopic composition is fixed at the time of tooth formation. Through studying both bone and dentine collagen from an individual, intra-individual changes can thus be observed (Cox and Sealy, 1997; Sealy et al., 1995).

Collagen extraction was carried out following a modified Longin method (Brown et al., 1988). This included demineralisation of the samples in 0.25 M HCl for approximately 48 h, after which the solution and inorganic material were removed through filtration. Organic material was dissolved in 0.01 M HCl, at 58 °C for c. 16 h, after which fragmented collagen chains and humic substances were removed via a 30 kDa ultrafilter. The residual solvent was frozen to approximately –80 °C and freeze dried. The isotope analyses were performed using a Carlo Erba NC2500 elemental analyser connected to a Finnigan MAT Delta+ isotope ratio mass spectrometer run in continuous flow at the Department of Geology and Geochemistry, Stockholm University. Precision, with a 95% confidence level, was $\pm 0.15\text{‰}$ for both $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$, and $\pm 2\text{‰}$ for $\delta^{34}\text{S}$.

Terrestrial carbon isotope fractionation occurs during photosynthesis, where three possible biosynthetic pathways, C_3 , C_4 and CAM, result in differing ranges of $\delta^{13}\text{C}$ values (Boutton, 1991; DeNiro, 1987). All terrestrial plants in central Scandinavia during the Stone Age follow the C_3 pathway. A terrestrial end value, i.e. the $\delta^{13}\text{C}$ value of an individual with a purely terrestrial diet, for the

Baltic area during the Stone Age has been estimated to between –20 and –21‰ (Lidén and Nelson, 1994). Isotopic fractionation of carbon in marine ecosystems is a complex process, influenced by the biosynthetic pathway (predominantly C_3 although the C_4 cycle has been identified as well), salinity, temperature and CO_2 availability (Boutton, 1991; Chisholm, 1989). A marine end value in the Baltic has been estimated to between –14 and –15‰, although the values have varied chronologically due to a complex natural history with fluctuating salinity levels (Eriksson and Lidén, 2002; Lidén and Nelson, 1994). Further, an increase in $\delta^{13}\text{C}$ with c. 1‰ for each step up the food chain has been observed (Schoeninger and DeNiro, 1984; Schoeninger, 1989). In Scandinavia, variations in carbon isotope ratios can be applied to distinguish between terrestrial and marine consumers.

Values of $\delta^{13}\text{C}$ in atmospheric CO_2 have varied due to variations in climate, causing a similar variation in plant $\delta^{13}\text{C}$ (van Klinken et al., 1994). Further, $\delta^{13}\text{C}$ in C_3 plants are highly sensitive to micro-environmental variations, which can cause local deviations from assumed dietary end values (Ambrose and Norr, 1993). The importance of establishing a local stable isotope ecology through faunal material of the same site and date has been stressed, especially regarding this particular region (Eriksson and Lidén, 2002; Eriksson, 2003). On sites where faunal material is present, baselines can be drawn from animal isotopic signatures, producing expectancy values for potential food sources (DeNiro, 1987; Eriksson, 2004).

Atmospheric nitrogen enters the biological system via nitrogen fixation by soil microorganisms and bacteria, or via root systems in the form of nitrate or ammonium (DeNiro, 1987; Sealy, 2001). $\delta^{15}\text{N}$ becomes enriched by approximately 3‰ for each step up the food chain (Minagawa and Wada, 1984; Schoeninger and DeNiro, 1984; Schwarcz and Schoeninger, 1991; Schwarcz et al., 1999). Since atmospheric nitrogen has a $\delta^{15}\text{N}$ value close to 0‰, plants will display values around 3‰, organisms living off these plants have values around 6‰ and so on. Since marine and freshwater food chains are much longer than terrestrial ones, marine top predators display markedly higher $\delta^{15}\text{N}$ values than their terrestrial counterparts. A land-living carnivore might display a $\delta^{15}\text{N}$ value of approximately 10–12‰, whereas seals can have $\delta^{15}\text{N}$ values around 18‰ (Schoeninger and DeNiro, 1984). This isotopic fractionation process of nitrogen also results in elevated $\delta^{15}\text{N}$ values in breastfeeding individuals, who obtain values one trophic level up relative to the mothers they are “preying” on. This presents possibilities to reconstruct the duration of breastfeeding and subsequent weaning through analysis of $\delta^{15}\text{N}$ in deciduous teeth (Fogel et al., 1989). Elevated $\delta^{15}\text{N}$ values have also been identified in arid areas, a phenomenon presumed to be the result of animals under drought stress stimulating their water conservation (Schwarcz and Schoeninger, 1991; Schwarcz et al., 1999).

Sulphur is incorporated into plants mainly through the soil, which has a $\delta^{34}\text{S}$ signature derived from the local bedrock. Processes of atmospheric deposition and microbial activities in the soil will also, to a varied degree, affect the plants' $\delta^{34}\text{S}$ value. Since isotopic fractionation of sulphur between food and consumer is very small (c. –1‰ to +2‰), the $\delta^{34}\text{S}$ value in bone collagen reflects the sulphur isotopic composition of the diet, which, in turn, is controlled by the local sulphur isotope ecology (Peterson et al., 1985; Richards et al., 2003).

Terrestrial sulphur isotopic compositions vary markedly between different geological settings. $\delta^{34}\text{S}$ values in sedimentary rocks range between the extremes –40 and +40‰. Igneous rocks have a more moderate isotopic range, where European granitic rocks display $\delta^{34}\text{S}$ values between ca –4 and +9‰, while $\delta^{34}\text{S}$ values in mafic rocks are close to 0‰. $\delta^{34}\text{S}$ in metamorphic rocks can vary between c. –20 and +20‰ (Faure and Mensing, 2005; Krouse, 1980). As a result, terrestrial vegetation includes a wide range of

sulphur isotopic compositions, although it appears to average near +2 to +6‰ over large areas (Peterson and Fry, 1987).

The $\delta^{34}\text{S}$ value of modern ocean water sulphate is rather uniform, averaging 21‰, with marine vegetation displaying values between ca. +17‰ to +21‰ (Peterson and Fry, 1987; Rees et al., 1978). In freshwater systems, values are much more dispersed, ranging between –22 and +20‰, mainly as a result of the reduction of sulphate ions (SO_4^-) to hydrogen sulphide (H_2S) by anaerobic bacteria, a process through which a depletion of ^{34}S occurs (Faure and Mensing, 2005; Krouse, 1980). Terrestrial plants in coastal areas often display a marine sulphur isotopic signal as the result of a sea spray effect, which carries marine sulphur particles inland. The geographical extension of this effect may be limited to a few kilometres but can, as in the case of New Zealand, include whole islands (Kusakabe et al., 1976; Wadleigh et al., 1994). Consequently, a marine isotopic signal in an individual does not necessarily imply the consumption of marine food sources, but rather the food sources' proximity to the sea (Richards et al., 2001).

Sulphur in type 1 collagen (constituting the collagen compound in bone and dentine) is found in the amino acid methionine, and is represented in much smaller quantities than carbon and nitrogen. Unlike $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ analyses, which are now well established in palaeodietary research, $\delta^{34}\text{S}$ have been sparsely applied in archaeological studies, but new techniques of mass spectrometry allowing smaller sample sizes of <10 mg (Giesemann et al., 1994) greatly increased the potentials of the method within this field.

Previous studies have proved the possibility to distinguish between terrestrial and marine consumers in prehistoric societies through $\delta^{34}\text{S}$ data from human bone collagen (Richards et al., 2001) and hair samples (Macko et al., 1999). The potential for discriminating between terrestrial and freshwater consumers in archaeological contexts has been tested by Privat et al. (2007), who emphasise the advantages of including $\delta^{34}\text{S}$ in palaeodietary studies, although problems with overlapping isotopic values between freshwater and terrestrial food sources can cause limitations to the interpretations of isotopic data. The characteristic of sulphur isotopic composition being locally or regionally specific presents possibilities of identifying migrants among archaeological populations and could reveal patterns of movement and interaction (Macko et al., 1999; Privat et al., 2007; Richards et al., 2003).

In Sweden, migrants have been identified through $\delta^{34}\text{S}$ analyses on skeletal material from the Viking Age cemetery at Birka, in the province of Södermanland, and the Late Viking Age/Early Medieval period cemetery at Björned, province of Ångermanland (Linderholm et al., 2008a,b). In contrast, a study on material from a TRB passage grave in Rössberga, province of Västergötland, Sweden, have shown remarkably homogenous $\delta^{34}\text{S}$ values together with terrestrial $\delta^{13}\text{C}$ values, clearly indicating a common geographical origin for all buried individuals (Linderholm et al., 2008c). There are distinct differences in the faunal reference data from these three Swedish sites, proving that local terrestrial sulphur isotope compositions within Sweden vary with different geographical regions. In their study of sulphur isotopic variations in marine fauna from northern Europe, Craig et al. (2006) identified markedly dispersed $\delta^{34}\text{S}$ and $\delta^{13}\text{C}$ values in six grey seals recovered from a coastal shell midden on eastern Jutland. The $\delta^{13}\text{C}$ values for three of these seals were consistent with known values for marine species in the Baltic, and were interpreted as originating from that area, whereas the three other samples were presumed to originate from North Sea seals. The $\delta^{34}\text{S}$ values of the supposedly Baltic seals ranged from 14.9 to 17.4‰, whereas two of the seals presumed to originate from the North Sea had values of 10.7 and 11.4‰.

Since sulphur isotope ratios varies between different geographical regions, it is important to establish the local sulphur isotope ecology, preferably through data on faunal species with small

home ranges. Further, since modern pollution affects the sulphur isotopic signal (Faure and Mensing, 2005: 543 pp.), valid reference values must be derived from material which is contemporaneous with the material analysed.

Materials

Samples selected for $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ analysis

The human samples selected for $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ analyses in this study included three buried individuals together with bones retrieved from the dump heaps, which are likely to represent material scattered throughout the cultural layer. The buried individuals were found in graves A1, A2, and A3 during the 1970 excavation (Olsson et al., 1994). Where possible, teeth were included into the analyses in order to trace potential intra-individual variations. Through sampling the primary dentine in the crowns of the permanent and deciduous teeth, isotopic data reflecting the diet during the time of crown formation of these teeth were obtained. Ages of crown formation in permanent molars and deciduous teeth are presented in Table 1.

A1 (ind. 14) contained a well-preserved child skeleton placed in crouched position with the head to the north-east. One small pottery fragment without ornaments was found close to the spinal cord. The age of the child was estimated to about four to five years based on the eruption of the first molar. Preserved deciduous teeth was included in the analysis in order to study the breastfeeding and subsequent weaning pattern of the individual.

A2 (ind. 13, uncertain grave) constituted a dark coloured structure containing a mandible from an adult human, situated close to a pile of burned stones. A curved chisel was placed under the mandible, and 0.3 m to the south a dog cranium was found, together with tightly packed fish bones. A clay bead was placed in one of the eye sockets of the dog cranium.

A3 (ind. 12) was a pit containing a poorly preserved skeleton of an adult human, placed stretched out on the back, with the head pointing to the west. Potsherds were found close to the skeleton, the ornamented fragments dated to the Early and/or Middle Neolithic.

The human samples from the cultural layer initially constituted five humeri from different individuals (ind. 1–5), together with two mandibles with molars (ind. 6 and 7), included in order to study intra-individual dietary patterns. After collagen extraction it became clear that three out of the five humeri displayed insufficient collagen preservation (Table 4). In order to obtain the highest possible MNI, four femora (ind. 8–11) were subsequently included in the analysis. MNI for the stray finds is five, including four adult or juvenile/adult femora and one humerus from a 5- to 7-year-old child.

The faunal diversity on the Korsnäs site makes it possible to establish thorough reference data on the local stable isotope ecology. Fifty-six samples representing 15 animal species were ana-

Table 1

Average ages of completed crown formation in teeth

Permanent teeth ^a		Deciduous teeth ^b	
Tooth	Age (years)	Tooth	Age (months)
M1	3.0 ± 1	di1	2.5
M2	7.5 ± 2	di2	3
M3	13.5 ± 2.5	dc	9
		dm1	5.5
		dm2	10

^a M1, M2, M3 = first, second and third permanent molars. From Hillson (1996: 189 pp.).

^b di1, di2 = first and second deciduous incisors, dc = deciduous canine, dm1, dm2 = first and second deciduous molars. From Lunt and Law (1974:605).

lysed with regard to $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$. These included representatives of various levels in the marine and terrestrial food webs, together with four dogs samples, including the cranium found in A2 (Table 3), and six specimens of pigs of varying sizes. These pigs were analysed in an attempt to examine whether the dietary pattern was homogenous throughout the species, and if there were indications in the diet as to whether any of the pigs had been domesticated.

Samples selected for $\delta^{34}\text{S}$ analysis

Samples from six human individuals and 22 faunal specimens were analysed with regard to stable sulphur isotopes. Human samples selected for $\delta^{34}\text{S}$ analysis included the four femora, the child humerus and the mandible together with a pool of the first and second molars (M1 and M2) from the individual in A2. The child in A1 had to be excluded since the amount of sampled material was restricted by antiquarian interests.

Samples selected for radiocarbon dating

In addition to the stable isotope analyses, seven human and four faunal collagen samples were selected for AMS radiocarbon dating. In 1978, three radiocarbon dates, based on β -decay dating methods, were obtained from faunal samples retrieved from a waste disposal pit on the site, yielding dates between 4560 ± 60 and 4190 ± 60 BP (uncalibrated) (Olsson et al., 1994, Table 2). Due to the fact that the radiocarbon dating method of that time required large sample sizes, each sample consisted of several pooled bones from unidentified species. The $\delta^{13}\text{C}$ values obtained in connection with the dating indicate a more marine influence in the earliest date than in the later ones. Therefore the apparent discrepancy in the dates of the samples might be the result of an age offset caused by the reservoir effect. An estimated reservoir effect correction of 320 years has been suggested for the Baltic Sea (Olsson, 1996), but since the complex natural history of the Baltic has caused the extent of the reservoir effect to fluctuate over time, the effect must be calculated separately for any given period and place. No closed contexts including bones from both terrestrial and marine species exist on the Korsnäs site, and an assessment of the extent of the age offset in this particular context therefore cannot be made. However, an age offset caused by the reservoir effect of approximately 70 ± 40 years has been established for Middle Neolithic PWC human bones from Gotland (Eriksson, 2004). Submitted samples included five individuals with uncertain contexts (individuals 5 and 8–11) together with the individuals from A1 and A2 (individuals 14 and 13). Faunal samples included the terrestrial species moose, bear, pig and dog.

Results

The results of the stable isotope analyses are presented in Tables 3 and 4, and Figs. 5–10. The analysed material proved to be in varied degrees of preservation, with collagen yields between 0.2% and 10.0%. Nineteen samples fell below the acceptable collagen yield minimum of 1% (van Klinken, 1999). These included all

three cod (KOR 57, 58, 59) together with one specimen of pike (KOR 28), two of beaver (KOR 05, 06) and one harp seal (KOR 108). Excluded human material comprised three out of five humeri (individuals 2, 3 and 4), both of the samples (mandible and first molar) from individual 6, the first molar from individual 7 and all four samples from individual 12 in A3. Finally, two samples had a collagen yield of 0.9%, but due to the visual appearance of the collagen, together with the fact that they fulfilled other stipulated quality criteria, these samples were not excluded from analysis. Two samples of harp seal (KOR 22, 23), one ringed seal (KOR 21) and one specimen of pike (KOR 27) had to be dismissed due to C/N ratios outside the acceptable range of 2.9–3.6 (DeNiro, 1985). All samples fell well within the acceptable ranges for C- and N-concentrations (Ambrose, 1990), displaying values of 32.5–43.1% and 12.0–16.0% for carbon and nitrogen respectively.

$\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ in the Korsnäs fauna

The results of the $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ analyses on the faunal samples are presented in Table 3 and Fig. 5. The herbivorous species moose and mountain hare had $\delta^{13}\text{C}$ values between -23.2 and -20.7‰ , and $\delta^{15}\text{N}$ values ranging from 1.9 to 2.6‰. A herbivorous diet is also likely for the brown bear, represented by two phalanges which might originate from the same individual. The two bear samples displayed $\delta^{13}\text{C}$ values of -20.2 and -20.0‰ and $\delta^{15}\text{N}$ values of 3.8 and 3.9‰. The terrestrial carnivore pine marten had $\delta^{13}\text{C}$ values between -20.3 and -19.5‰ , and $\delta^{15}\text{N}$ values from 7.3 to 8.1‰, while the isotopic signal of the badger corresponded to a semi-terrestrial carnivore, -18.9 and 9.7‰ for $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ respectively. The diet of badgers is highly varied, including earthworms, insects, small mammals, bird eggs, reptiles and amphibians (Curry-Lindahl, 1988), and isotopic signatures will vary accordingly.

The six samples representing pig yielded very uniform values between -22.1 and -21.3‰ for $\delta^{13}\text{C}$ and 4.3 to 4.8‰ for $\delta^{15}\text{N}$. Mean and s.d. was $-21.7 \pm 0.3\text{‰}$ for $\delta^{13}\text{C}$ and $4.6 \pm 0.2\text{‰}$ for $\delta^{15}\text{N}$. The values for the pigs overlapped with the two specimens of the herbivorous beaver, with $\delta^{13}\text{C}$ values of -21.8‰ and -21.3‰ , and $\delta^{15}\text{N}$ values of 4.4 and 4.8‰, respectively. The pigs' carbon and nitrogen isotopic signals, together with the high correlation to the beaver values, suggest a predominantly terrestrial herbivorous diet for this species.

The fish-eating white winged scoters displayed varied isotopic signatures. The $\delta^{13}\text{C}$ values were the most dispersed, where one specimen displayed a clearly terrestrial value of -21.2‰ , whereas the other two had more marine values of -16.1 and -17.1‰ . The specimen with the terrestrial $\delta^{13}\text{C}$ value displayed a $\delta^{15}\text{N}$ value of 8.5‰, differing with the equivalent of one trophic level from the $\delta^{15}\text{N}$ values of the two other scoters, 11.1 and 11.6‰. Modern white winged scoters in the region breed along the Baltic coast as well as in terrestrial environments, mainly the mountain lakes and coniferous forests of Northern Scandinavia (Lundevall and Bergström, 2005), and differences in breeding environments might explain the variations in $\delta^{13}\text{C}$ values between the individuals.

$\delta^{13}\text{C}$ values for herring ranged from -15.5 to -13.8‰ while the two samples of pike had higher values of -12.3 and -12.2‰ . Pike live in freshwater as well as in brackish littoral environments, such as the shallow water close to the Baltic coast, while herring is a pelagic fish (Curry-Lindahl, 1985). Studies have shown that species living in littoral environments are enriched in $\delta^{13}\text{C}$ compared to pelagic species (France, 1995), and this might explain the difference in $\delta^{13}\text{C}$ values between pike and herring. $\delta^{15}\text{N}$ values for herring and pike ranged between 9.2 and 11.7‰, pike displaying the highest values. This might be the result of a higher trophic level for the analysed pike than for the herring samples. The otters are found about one trophic level above the fish samples, with very dispersed $\delta^{13}\text{C}$ values ranging from -14.2 to -9.2‰ , and $\delta^{15}\text{N}$ val-

Table 2
Radiocarbon dates from 1978

^{14}C lab ID	^{14}C BP	$\delta^{13}\text{C}$ (‰) ^a
Lu-1285	4190 ± 60	-20.8
Lu-1286	4270 ± 60	-19.5
Lu-1287	4560 ± 60	-17.9

Samples consist of pooled bones from unidentified species (Olsson et al., 1994).

^a $\delta^{13}\text{C}$ values obtained in connection with the radiocarbon dating.

Table 3
Carbon, nitrogen and sulphur isotopic data for the faunal samples from Korsnäs

Species	Common name	Element	lab ID	Bone/dentine (mg)	Collagen (mg)	Collagen (%)	$\delta^{13}\text{C}$ (‰)	$\delta^{15}\text{N}$ (‰)	% C	% N	C/N	$\delta^{34}\text{S}$ (‰)	% S	C/S	N/S
<i>Alces alces</i>	Moose	Calcaneus	KOR 01	71.7	3.0	4.2	-21.8	1.9	44.1	15.2	3.4				
<i>Alces alces</i>	Moose	Calcaneus	KOR 02	158.4	10.0	6.3	-21.1	2.1	44.9	15.4	3.4	6.7	0.29	413	121
<i>Alces alces</i>	Moose	Calcaneus	KOR 03	67.6	1.3	1.9	-23.2	2.6	43.9	14.4	3.6				
<i>Canis familiaris</i>	Dog	Cranium	KOR 36	48.9	0.9	1.9	-15.1	13.8	37.9	14.0	3.2				
<i>Canis familiaris</i>	Dog	Ulna	KOR 37	267.1	13.4	5.0	-13.7	14.1	42.2	15.5	3.2	16.8	0.17	662	208
<i>Canis familiaris</i>	Dog	Ulna	KOR 38	71.9	1.1	1.6	-15.2	12.8	38.6	13.8	3.3				
<i>Canis familiaris</i>	Dog	Ulna	KOR 39	68.1	0.7	1.0	-15.5	14.5	35.3	11.9	3.5				
<i>Castor fiber</i>	Beaver	Talus	KOR 04	71.4	0.7	1.0	-21.8	4.8	41.0	13.6	3.5				
<i>Castor fiber</i>	Beaver	Talus	KOR 05	99.5	0.2	0.2	—	—	—	—	—				
<i>Castor fiber</i>	Beaver	Talus	KOR 06	71.1	0.1	0.2	—	—	—	—	—				
<i>Castor fiber</i>	Beaver	Talus	KOR 29	172.4	4.2	2.4	-21.3	4.4	42.4	15.6	3.2	6.2	0.28	405	128
<i>Clupea harengus</i>	Herring	Vertebrae	KOR 60	280.2	5.6	2.0	-14.4	10.0	42.2	15.5	3.2	18.0	0.32	352	111
<i>Clupea harengus</i>	Herring	Vertebrae	KOR 61	176.3	6.3	3.6	-13.8	9.2	42.3	15.7	3.1	13.0	0.34	332	106
<i>Clupea harengus</i>	Herring	Vertebrae	KOR 62	68.1	2.1	3.0	-15.5	9.6	43.1	15.5	3.3				
<i>Esox lucius</i>	Pike	Parasphenoid	KOR 25	63.3	1.1	1.7	-12.3	11.7	40.6	14.5	3.3				
<i>Esox lucius</i>	Pike	Dentale	KOR 26	39.0	0.7	1.8	-12.2	10.0	29.3	10.0	3.4				
<i>Esox lucius</i>	Pike	Dentale	KOR 27	66.1	1.0	1.5	-12.7	13.7	42.3	13.4	3.7				
<i>Esox lucius</i>	Pike	Dentale	KOR 28	55.0	0.3	0.6	—	—	—	—	—				
<i>Gadus morhua</i>	Cod	Premaxillary	KOR 57	62.0	0.2	0.5	—	—	—	—	—				
<i>Gadus morhua</i>	Cod	Vertebra	KOR 58	61.1	0.2	0.3	—	—	—	—	—				
<i>Gadus morhua</i>	Cod	Vertebra	KOR 59	52.0	0.2	0.4	—	—	—	—	—				
<i>Lepus timidus</i>	Mountain hare	Tibia	KOR 32	121.1	7.7	6.3	-22.0	2.2	42.6	15.5	3.2	13.1	0.24	474	148
<i>Lepus timidus</i>	Mountain hare	Tibia	KOR 33	151.9	8.7	5.8	-20.7	2.4	42.7	15.7	3.2	11.7	0.19	600	189
<i>Lutra lutra</i>	Otter	Radius	KOR 10	89.2	8.2	9.2	-9.9	12.1	45.4	16.0	3.3	12.6	0.25	485	147
<i>Lutra lutra</i>	Otter	Radius	KOR 11	78.3	5.2	6.7	-11.3	13.9	44.9	15.9	3.3				
<i>Lutra lutra</i>	Otter	Ulna	KOR 12	73.0	7.3	10.0	-14.2	12.5	45.8	15.7	3.4	10.2	0.22	556	163
<i>Lutra lutra</i>	Otter	Pelvis	KOR 30	73.5	4.7	6.4	-9.2	11.3	43.3	16.1	3.1				
<i>Martes martes</i>	Pine marten	Humerus	KOR 07	57.4	3.0	5.2	-20.2	7.3	44.3	15.6	3.3				
<i>Martes martes</i>	Pine marten	Humerus	KOR 08	58.8	5.1	8.7	-19.5	8.1	44.4	15.7	3.3	6.1	0.27	439	133
<i>Martes martes</i>	Pine marten	Humerus	KOR 09	60.8	5.7	9.4	-20.3	7.7	44.8	15.6	3.4	10.9	0.26	460	137
<i>Melanitta fusca</i>	Scoter	Coracoid	KOR 54	59.2	4.1	7.0	-16.0	11.1	43.7	15.7	3.2	17.2	0.20	583	180
<i>Melanitta fusca</i>	Scoter	Coracoid	KOR 55	59.2	4.9	8.3	-17.1	8.5	41.2	15.1	3.2	17.2	0.20	549	173
<i>Melanitta fusca</i>	Scoter	Coracoid	KOR 56	61.3	1.3	2.1	-21.2	11.6	38.7	13.6	3.3				
<i>Meles meles</i>	Badger	Ulna	KOR 31	71.5	3.0	4.2	-18.9	9.7	42.8	15.7	3.2				
<i>Ph. groenlandica</i>	Harp seal	Temporal	KOR 105	121.9	1.2	1.0	-17.0	12.0	43.9	14.8	3.5				
<i>Ph. groenlandica</i>	Harp seal	Temporal	KOR 106	82.8	1.3	1.5	-15.3	14.9	43.0	14.3	3.5				
<i>Ph. groenlandica</i>	Harp seal	Temporal	KOR 107	118.0	2.0	1.7	-16.4	13.4	44.4	15.4	3.4				
<i>Ph. groenlandica</i>	Harp seal	Temporal	KOR 108	127.4	0.8	0.6	-15.8	13.9	39.9	13.4	3.5				
<i>Ph. groenlandica</i>	Harp seal	Temporal	KOR 109	346.8	6.0	1.7	-15.8	13.4	44.6	15.0	3.5	19.8	0.18	661	191
<i>Ph. groenlandica</i>	Harp seal	Radius	KOR 110	82.9	5.2	6.2	-16.1	13.9	45.8	16.5	3.2	16.4	0.12	1018	314
<i>Ph. groenlandica</i>	Harp seal	Temporal	KOR 22	71.7	1.1	1.5	-17.8	13.4	45.3	14.0	3.8				
<i>Ph. groenlandica</i>	Harp seal	Temporal	KOR 23	70.1	0.6	0.8	-17.3	15.2	45.0	12.9	4.1				
<i>Ph. groenlandica</i>	Harp seal	Temporal	KOR 24	276.9	7.4	2.7	-16.4	12.4	44.1	15.0	3.4	16.7	0.29	406	119
<i>Phoca hispida</i>	Ringed seal	Temporal	KOR 111	250.3	4.5	1.8	-16.6	13.8	45.6	15.5	3.4	14.4	0.19	640	187
<i>Phoca hispida</i>	Ringed seal	Humerus	KOR 112	73.2	3.5	4.7	-15.7	12.1	45.3	15.8	3.3	14.4	0.16	755	227
<i>Phoca hispida</i>	Ringed seal	Temporal	KOR 19	115.1	1.1	0.9	-16.5	12.3	45.9	14.9	3.6				
<i>Phoca hispida</i>	Ringed seal	Temporal	KOR 20	283.4	5.5	1.9	-17.7	13.1	42.7	14.0	3.6	14.1	0.26	439	123
<i>Phoca hispida</i>	Ringed seal	Temporal	KOR 21	74.7	0.7	0.9	-15.4	12.7	44.2	13.1	3.9				
<i>Sus scrofa</i>	Pig	Talus	KOR 13	90.6	3.4	3.8	-21.8	4.6	45.5	15.2	3.5				
<i>Sus scrofa</i>	Pig	Talus	KOR 14	196.5	6.8	3.5	-22.0	4.6	42.4	15.1	3.3	6.9	0.27	419	128
<i>Sus scrofa</i>	Pig	Talus	KOR 15	78.7	1.5	1.9	-21.5	4.8	41.3	14.2	3.4				
<i>Sus scrofa</i>	Pig	Talus	KOR 16	84.5	0.8	1.0	-21.7	4.6	40.8	13.4	3.5				
<i>Sus scrofa</i>	Pig	Talus	KOR 17	87.7	1.0	1.1	-21.9	4.8	40.8	13.7	3.5				
<i>Sus scrofa</i>	Pig	Talus	KOR 18	164.8	11.1	6.7	-21.3	4.3	44.0	15.8	3.2	8.3	0.20	587	181
<i>Ursus arctos</i>	Brown bear	Metacarpus 3	KOR 34	71.3	0.6	0.9	-20.2	3.9	35.7	12.7	3.3				
<i>Ursus arctos</i>	Brown bear	Metatarsus 3	KOR 35	229.8	7.2	3.1	-20.0	3.8	41.7	15.5	3.1	7.4	0.18	619	198

Samples are excluded since they fall outside quality ranges.

ues between 11.3 and 13.9‰. The values indicate marine food sources, where the individuals with the highest $\delta^{13}\text{C}$ value seem to have been eating predominantly littoral fish.

The harp seals displayed $\delta^{13}\text{C}$ values between -17.0 and -15.3‰, with $\delta^{15}\text{N}$ values ranging from 12.0 to 14.9‰. The corresponding values for ringed seals ranged from -17.7 to -15.7‰ ($\delta^{13}\text{C}$) and 12.1 to 13.8‰ ($\delta^{15}\text{N}$). The results do not indicate any marked differences in the carbon and nitrogen isotopic data between the two species. The seals generally have lower $\delta^{13}\text{C}$ values than the fish, which might be explained by the differences in $\delta^{13}\text{C}$ values between pelagic and littoral consumers, or by different prey or foraging areas.

The dogs had $\delta^{13}\text{C}$ values between -15.5 and -13.7‰, $\delta^{15}\text{N}$ values range from 12.8 to 14.5‰. The data indicate that the dogs fed predominantly off fish and seal.

$\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ in the Korsnäs humans

The results of the carbon and nitrogen stable isotope analyses on the human samples are presented in Table 4 and Figs. 6–8. Values ranged between -16.5 and -13.1‰ for $\delta^{13}\text{C}$, and from 15.1‰ to 16.6‰ for $\delta^{15}\text{N}$. The mean value for all human samples together was -15.2 ± 1.0 ‰ for $\delta^{13}\text{C}$, and 15.7 ± 0.3 ‰ for $\delta^{15}\text{N}$. The values clearly indicate an intake of predominantly marine protein. $\delta^{15}\text{N}$

Table 4
Carbon, nitrogen and sulphur isotopic data for the human samples from Korsnäs

Ind. no./age	Context	Element	Lab ID	Bone/dentine (mg)	Collagen (mg)	Collagen (%)	$\delta^{13}\text{C}$ (‰)	$\delta^{15}\text{N}$ (‰)	% C	% N	C/N	$\delta^{34}\text{S}$ (‰)	% S	C/S	N/S
Ind. 1 adult		Humerus	KOR 40	93.9	1.3	1.4	-16.0	15.5	39.0	14.1	3.2				
Ind. 2 adult		Humerus	KOR 41	85.8	0.3	0.4	-	-	-	-	-				
Ind. 3 adult		Humerus	KOR 42	79.2	0.3	0.4	-	-	-	-	-				
Ind. 4 adult		Humerus	KOR 43	72.3	0.3	0.4	-	-	-	-	-				
Ind. 5 child		Humerus	KOR 44	284.3	16.7	5.9	-15.1	15.5	41.2	15.2	3.2	16.7	0.15	733	233
Ind. 6 adult		Mandible	KOR 45	98.9	0.4	0.4	-	-	-	-	-				
Ind. 6 adult		M1	KOR 46	63.1	0.4	0.6	-	-	-	-	-				
Ind. 7 adult		Mandible	KOR 47	71.1	1.6	2.2	-16.2	15.8	39.9	14.5	3.2				
Ind. 7 adult		M1	KOR 48	57.0	0.3	0.4	-	-	-	-	-				
Ind. 7 adult		M2	KOR 49	58.7	0.8	1.4	-15.2	15.6	38.3	13.6	3.3				
Ind. 8 adult		Femur	KOR 50	171.2	10.4	6.1	-14.8	15.7	43.1	16.0	3.1	12.9 ± 0.9 ^a	0.41	281	89
Ind. 9 adult		Femur	KOR 51	897.8	9.5	1.1	-16.0	15.6	37.7	13.4	3.3	13.1 ± 0.1 ^a	0.40	252	77
Ind. 10 adult		Femur	KOR 52	911.2	14.9	1.6	-15.5	15.4	39.8	14.4	3.2	12.1 ± 0.1 ^a	0.35	304	94
Ind. 11 juv./adult		Femur	KOR 53	950.5	14.9	1.6	-15.6	15.1	40.5	14.3	3.3	12.9 ± 0.3 ^a	0.35	309	93
Ind. 12 adult	Grave A3	M2	KOR 63	74.0	0.2	0.2	-	-	-	-	-				
Ind. 12 adult	Grave A3	M3	KOR 64	72.7	0.3	0.5	-	-	-	-	-				
Ind. 12 adult	Grave A3	M1	KOR 65	59.5	0.2	0.3	-	-	-	-	-				
Ind. 12 adult	Grave A3	Mandible	KOR 66	70.3	0.2	0.3	-	-	-	-	-				
Ind. 13 adult	Grave A2	M2	KOR 67	123.6	4.0	3.2	-13.1	15.5	39.7	14.9	3.1	12.2 ^b	0.18	589	189
Ind. 13 adult	Grave A2	M1	KOR 68	55.5	1.4	2.5	-13.7	15.4	40.2	14.9	3.1	12.2 ^b			
Ind. 13 adult	Grave A2	Mandible	KOR 69	349.9	9.6	2.7	-13.8	15.7	41.2	15.3	3.1	14.7	0.12	917	292
Ind. 14 child	Grave A1	Mandible	KOR 70	126.5	3.9	3.1	-15.2	16.2	41.7	15.4	3.2				
Ind. 14 child	Grave A1	M1	KOR 71	63.2	1.1	1.8	-15.2	15.6	40.4	14.7	3.2				
Ind. 14 child	Grave A1	dm2	KOR 72	40.1	0.7	1.7	-16.1	15.9	38.1	13.0	3.4				
Ind. 14 child	Grave A1	dm1	KOR 73	38.2	0.6	1.7	-15.4	16.6	32.5	12.1	3.1				
Ind. 14 child	Grave A1	dc	KOR 74	41.0	0.5	1.3	-16.5	15.8	36.0	12.0	3.5				

Samples are excluded since they fall outside quality ranges.

^a Average value (± 1 s.d.) of duplicate runs.

^b Sample comprising a pool of M1 and M2.

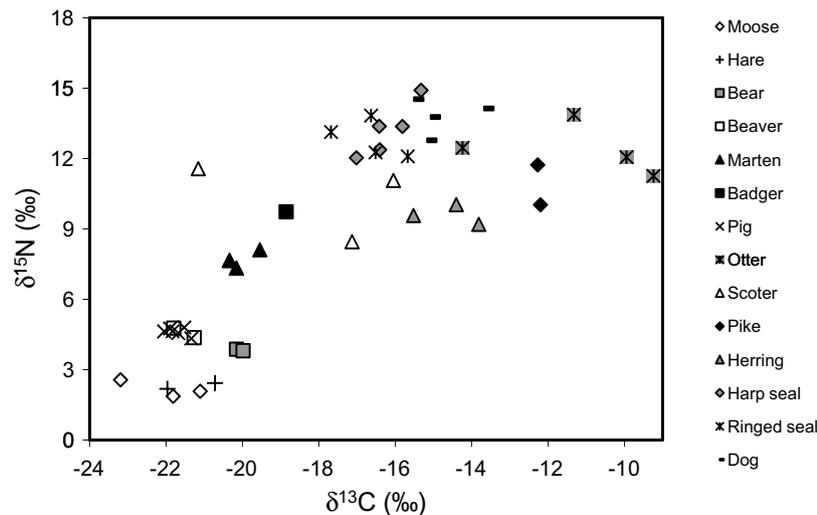


Fig. 5. Plot of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values for the Korsnäs faunal samples. Precision (95% confidence level) is $\pm 0.15\text{‰}$ for both carbon and nitrogen.

values were all about 3‰ higher than $\delta^{15}\text{N}$ values for the seals. The child in A1, individual 14, displayed elevated $\delta^{15}\text{N}$ values compared to the other samples, probably as a result of breastfeeding. $\delta^{13}\text{C}$ values were more dispersed, the main part were more than 1‰ higher than seal $\delta^{13}\text{C}$ values. Individual 13 in A2 deviated through higher $\delta^{13}\text{C}$ values. The lowest $\delta^{13}\text{C}$ values represented individuals 1, 7 and 9. These three samples, a humerus, a femur and a mandible, all adult, retrieved from the cultural layer, displayed very similar isotopic signatures, and it cannot be ruled out that they originate from the same individual. The human samples from the cultural layer had a total isotopic range of -16.2 to -14.8‰ for $\delta^{13}\text{C}$, with a mean of $-15.6 \pm 0.5\text{‰}$, and 15.1 to 15.8‰ for $\delta^{15}\text{N}$, with a mean of $15.6 \pm 0.5\text{‰}$.

Isotopic data from both bone and teeth were obtained from individuals 7, 13 and 14 (Fig. 7). Individual 7 showed a decrease

in the $\delta^{13}\text{C}$ value of 1‰ (from -15.2 to -16.2‰) between the age of c. 7.5 years and adulthood. The $\delta^{15}\text{N}$ value increased 0.2‰ during the same period (from 15.6 to 15.8‰). The results for individual 13 shows that between the ages c. 3 and c. 7.5 years, the $\delta^{13}\text{C}$ value increased with 0.6‰ (from -13.7 to -13.1‰), and $\delta^{15}\text{N}$ values increased with 0.1‰ (from 15.4 to 15.5‰), i.e. within the margin of error. The mandible displayed a $\delta^{13}\text{C}$ value of -13.8‰ during adulthood, a decrease of 0.7‰ compared to the second molar, and the $\delta^{15}\text{N}$ value increased with 0.2‰ to 15.7‰ during the same period. The results did not indicate any major changes in diet for either of the two individuals.

Teeth from the child in A1, individual 14, were analysed in an attempt to reconstruct the child's breastfeeding (Fig. 8). Since formation of deciduous teeth is initialised in utero, the teeth display an average of $\delta^{15}\text{N}$ values from before and after birth. Elevated val-

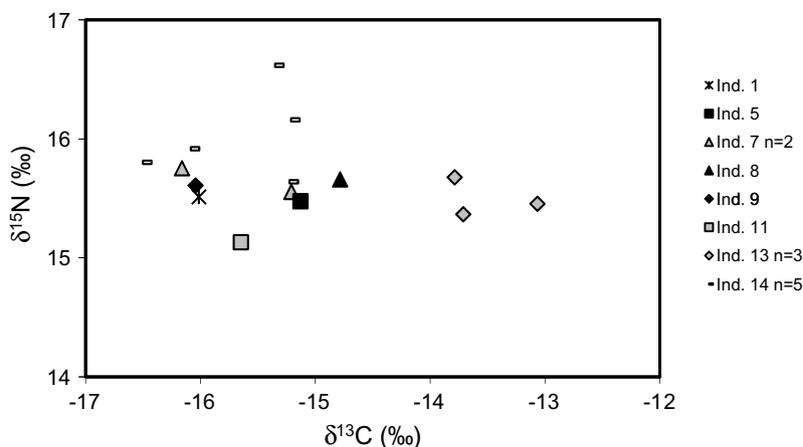


Fig. 6. Plot of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values for the Korsnäs human samples. Precision (95% confidence level) is $\pm 0.15\text{‰}$ for both carbon and nitrogen. n = number of analysed samples.

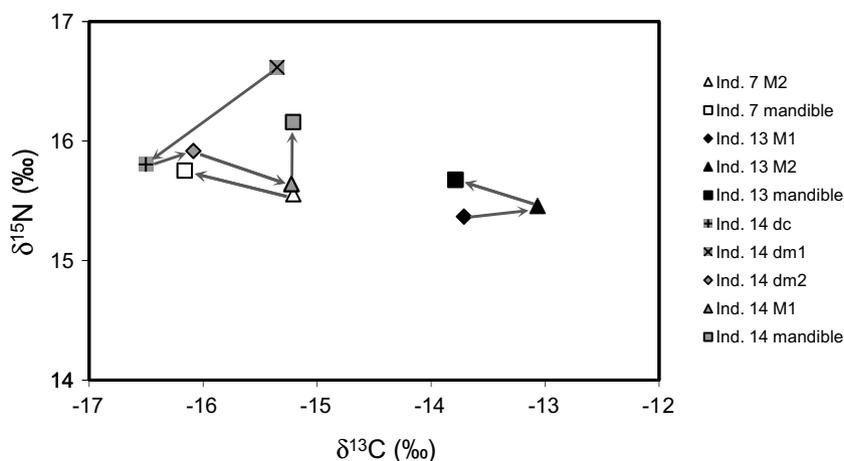


Fig. 7. Intra-individual changes in $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values studied through bone and dentine samples from individuals 7, 13 and 14 from Korsnäs. The plot shows only minor indications of dietary changes during the life of any of the adult individuals. The most elevated $\delta^{15}\text{N}$ value for individual 14 is an effect of breastfeeding. Precision (95% confidence level) is $\pm 0.15\text{‰}$ for both carbon and nitrogen.

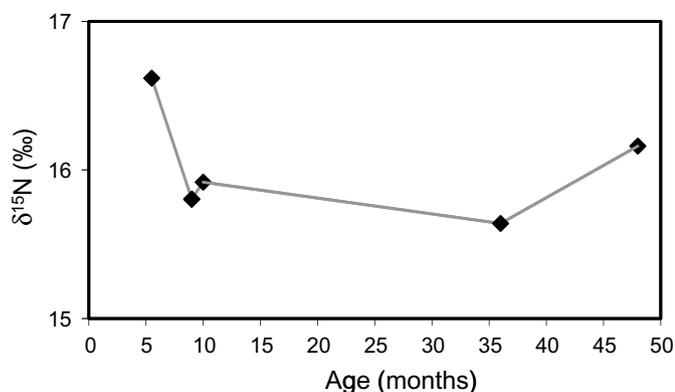


Fig. 8. Ind. 14 from Korsnäs. $\delta^{15}\text{N}$ values plotted against crown formation age of dm_1 , dc , dm_2 , and M_1 , and age estimated to be represented by the mandible sample. The drop in the $\delta^{15}\text{N}$ value between dm_1 and dm_2 indicates that weaning was initiated at an age of five to six months. Precision (95% confidence level) is $\pm 0.15\text{‰}$ for nitrogen. Data on crown formation ages from Hillson (1996: 189 pp.), Lunt and Law (1974:605).

ues will therefore not be as high as one trophic level, i.e. 3‰ (Liden et al., manuscript). The first deciduous molar (dm_1), representing an age of up to 5.5 months, displayed an elevated $\delta^{15}\text{N}$ value of 16.6‰. At the ages of c. 9 and c. 10 months (represented by a decid-

uous canine, dc , and the second deciduous molar, dm_2), the $\delta^{15}\text{N}$ value had decreased to 15.8 and 15.9‰, respectively. A similar value, 15.6‰ was given for the first molar, representing c. 3 years of age. The mandible, probably reflecting the last year of life, i.e. c. 4 years of age, had a slightly higher value of 16.2‰. The results indicate that the weaning process was initiated before the age of c. 5–6 months, and that the process appears to have ended somewhere between c. 10 and c. 36 months. The $\delta^{13}\text{C}$ values for this individual showed a decrease from -15.4 to -16.1‰ between c. 5.5 and c. 10 months. At an age of c. 3 years the value had increased to -15.2‰ , and the same value was represented in the mandible sample.

Sulphur quality

The results of the $\delta^{34}\text{S}$ analysis are presented in Tables 3 and 4. Total sulphur concentration in the samples ranged between 0.12 and 0.41%. Theoretical sulphur concentrations in modern type 1 collagen vary between species, in mammals averaging approximately 0.20–0.25%, based on UniProt Protein Knowledgebase database, e.g. *Homo sapiens* 0.22%, (UniProt # P02452, P08123), *Canis familiaris* 0.25% (UniProt # Q9XSJ7, O46392), *Bos taurus* 0.20% (UniProt # P02453, P02465), *Rattus norvegicus* 0.24% (UniProt # P02454, P02466). In analogy with carbon and nitrogen, the concentrations of sulphur in extracted collagen can vary, and the C/S or N/S ratios have been suggested to be a more reliable indicator of col-

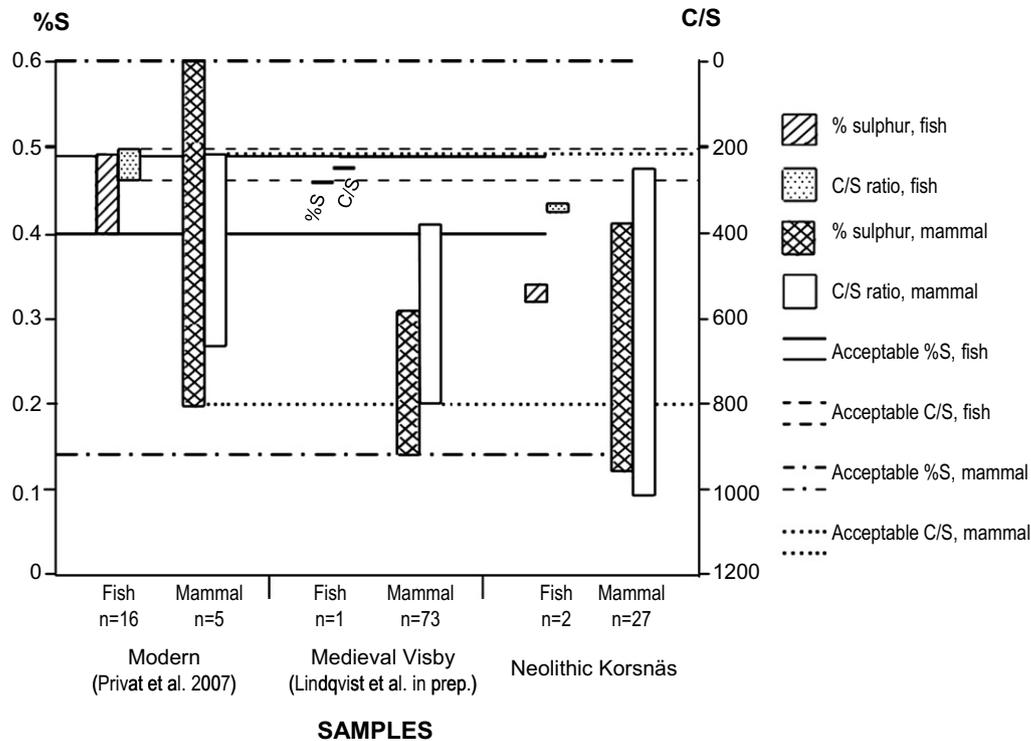


Fig. 9. Graph showing sulphur concentrations (%S) and C/S ratios for fish and mammal samples from Korsnäs, together with values from modern samples (Privat et al., 2007), and medieval samples from the town of Visby on Gotland (Lindqvist et al., in preparation). Lines marking acceptable sulphur concentrations and C/S ratios for mammal and fish are based on values from the modern and medieval samples. The samples from Korsnäs which fall outside the acceptable ranges are excluded from further analysis. n = number of analysed samples.

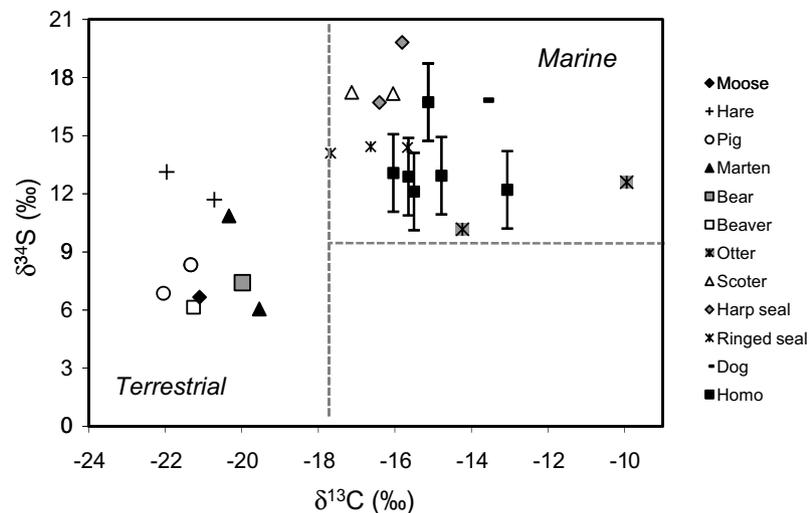


Fig. 10. Plot of isotopic $\delta^{13}\text{C}$ and $\delta^{34}\text{S}$ values for the faunal and human samples from Korsnäs. Error bars marking the 95% confidence level are applied for $\delta^{34}\text{S}$ on the human samples. Approximated ranges for marine $\delta^{13}\text{C}$ and $\delta^{34}\text{S}$ values, based on the Korsnäs faunal data, are demarcated with dashed lines. Ranges for terrestrial $\delta^{34}\text{S}$ values are further discussed in the text. Precision (95% confidence level) is $\pm 0.15\text{‰}$ for carbon, $\pm 2\text{‰}$ for sulphur.

lagen sulphur integrity than sulphur content (Privat et al., 2007; Richards et al., 2001). Since the C/S and N/S ratios correlated entirely in the analysed samples (regression analysis $R^2 = 0.990$, $p = 0.000$, $n = 29$), it is sufficient to apply either one of the two parameters, together with sulphur concentration, as a collagen sulphur quality indicator. Accordingly, only C/S ratios will be discussed in the following. The C/S ratios of the analysed samples ranged between 252 and 1018. Theoretical C/S ratios (calculated from UniProt Protein Knowledgebase database, see references above) in mammals average approximately 600, e.g. *Homo sapiens*:

634, *Canis familiaris*: 548, *Bos taurus*: 667, *Rattus norvegicus*: 571. (theoretical N/S ratios for the same species are 204, 176, 215 and 184, respectively).

Empirical data on sulphur concentration and C/S ratios in extracted bone collagen from modern material is scarce. Twenty-one modern samples have been analysed as reference material by Privat et al. (2007), yielding sulphur concentrations between 0.19 and 0.60% and C/S ratios from 209 to 666. Sixteen of these samples originate from fish bone collagen, and since the methionine content in fish is generally higher than in mammals (Eastoe,

1957; UniProt # Q6P4U1, Q6IQX2, Q6NZ15) these samples can only be considered useful as references concerning collagen sulphur integrity in fish species. Sulphur concentration and C/S ratios in these fish samples range 0.40–0.49% and 209–285, respectively. The remaining five samples, representing one cow and four humans, yielded sulphur concentrations between 0.19 (cow) and 0.60% (human), with corresponding C/S ratios between 212 and 666. Since these five modern samples could not be considered sufficient data on collagen sulphur integrity in mammals, the Korsnäs samples were further compared with stable isotope data on medieval bone material from the Swedish town of Visby on the island Gotland (Lindkvist et al., in preparation). The calciferous soils on Gotland present ideal preservation conditions, and the medieval Visby samples were therefore considered to be the best available reference material in addition to the modern samples analysed by Privat et al. (2007). The data comprised 73 mammals (including 53 humans) and one fish sample, all with collagen yields (2.9–14.5%), carbon and nitrogen concentrations and C/N ratios within the acceptable ranges. Collagen from the Visby samples had been extracted following the same protocol as the Korsnäs samples, including 30 kDa ultrafiltration, whereas the collagen samples from Privat et al. (2007) included 10 kDa ultrafiltered residues and therefore might have a methionine content deviating from that which would have been obtained with 30 kDa ultrafilters. Sulphur concentration for the Visby mammal samples ranged between 0.14 and 0.31%, both values representing humans, and C/S ratios ranged from 383 to 801. Corresponding values for the fish sample (*Gadus morhua*) were 0.46% and 249%.

To conclude, collagen sulphur in the Korsnäs samples was considered intact when the sulphur concentration fell within the range 0.14–0.60% for mammals, 0.40–0.49% for fish, provided that the C/S ratio was 212–801 for mammals, and 209–285 for fish (see Fig. 9). More data on collagen sulphur in modern material from a variety of species is needed in order to establish thorough and reliable quality criteria, and therefore the parameters applied here will most probably be modified in the future. Four samples fell well outside the acceptable ranges and are therefore excluded from further analysis and discussion. These represented both specimens of herring (KOR 60, 61), one harp seal (KOR 110) and the mandible of individual 13 (KOR 69).

$\delta^{34}\text{S}$ in the Korsnäs fauna

The results of the $\delta^{34}\text{S}$ analyses on the faunal samples are presented in Table 3 and Fig. 10. The terrestrial fauna, moose, mountain hare, marten, pig and bear, displayed $\delta^{34}\text{S}$ values between 6.1 and 13.1‰. The highest values (11.7 and 13.1‰) represented mountain hare, whose digestive system, involving refection, might affect the isotopic signal. A possible explanation for the high $\delta^{34}\text{S}$ values is that these hares have fed on plants affected by Sea spray aerosols due to, for example, a higher exposure to wind (cf. Angerbjörn and Pehrson, 1987). The mean value for the terrestrial fauna excluding hare was $7.7 \pm 1.7\text{‰}$, with pine marten representing both the lowest and the highest value (6.1 and 10.9‰). This might imply extensive home ranges or different geographical origins for the two marten specimens, alternatively, the highest value might be the result of consumption of herbivores feeding off Sea spray affected plants. $\delta^{34}\text{S}$ for the beaver, feeding on freshwater plants, was 6.2‰.

The two white winged scoters analysed with regard to $\delta^{34}\text{S}$ both displayed a value of 17.2‰. The $\delta^{13}\text{C}$ signatures of these samples indicated an extensive intake of marine protein. The mean $\delta^{34}\text{S}$ value for the marine fauna, including harp seal, ringed seal and otter (with $\delta^{13}\text{C}$ values indicating a diet consisting of predominantly marine fish) was $14.6 \pm 3.0\text{‰}$, with values ranging between 10.2 and 19.8‰. The two lowest values, 10.2 and 12.6‰, belonged to the otter samples, these might be explained by the littoral hab-

itat indicated in the $\delta^{13}\text{C}$ data of this species. In such an environment, substantial input of river water could markedly lower the $\delta^{34}\text{S}$ value. The three ringed seals yielded very homogenous values (14.1, 14.4 and 14.4‰), and are likely to have a common geographical origin. The two harp seals, on the other hand, displayed higher and more deviating values of 16.7 and 19.8‰, which might be explained by the fact that harp seals are migratory in contrast to the more stationary ringed seals (Curry-Lindahl, 1988), and that the two harp seals might have had different migratory patterns. The $\delta^{34}\text{S}$ values for the Korsnäs seals are consistent with isotopic data from the three grey seals of supposed Baltic Sea origin recovered on Jutland (Craig et al., 2006), which strengthens the plausibility of interpreting these Jutland seals as originating from the Baltic. Unfortunately, none of the herring samples fulfilled the quality criteria for collagen sulphur, and so reliable $\delta^{34}\text{S}$ values for potential consumers of marine fish could not be obtained. The dog displayed a $\delta^{34}\text{S}$ value of 16.8‰, which, in line with the $\delta^{13}\text{C}$ signature indicates a predominantly marine protein intake.

In Fig. 10, approximated ranges for marine $\delta^{13}\text{C}$ and $\delta^{34}\text{S}$ values in the Korsnäs region, based on the Korsnäs faunal data, are marked with dashed lines. The marine end value of -17.7‰ (the lowest marine value, represented by a ringed seal) is rather straight forward, whereas the range for marine $\delta^{34}\text{S}$ values, approximated here to ca. 10‰, is more problematic to appreciate. The lowest marine sulphur isotope values are displayed by the otter samples, probably dwelling in a littoral environment with consecutively low $\delta^{34}\text{S}$. Nevertheless, they have been included in the marine $\delta^{34}\text{S}$ range, since they seem have fed on (littoral) marine rather than terrestrial fish. It should further be noted the 2‰ precision (95 % confidence interval) poses additional problems regarding establishing marine $\delta^{34}\text{S}$ ranges. Local terrestrial $\delta^{34}\text{S}$ values in the region seem to partly overlap the marine values. As pointed out above, the high values for the two hares and the high $\delta^{34}\text{S}$ marten might be a result of Sea spray aerosols affecting the sulphur isotopic composition of plants consumed by these hares. If excluding these three samples, the remaining six terrestrial faunal samples range between 6.1 and 8.3‰, well in line with observed values for European granitic rocks (Faure and Mensing, 2005).

$\delta^{34}\text{S}$ in the Korsnäs humans

The results of the $\delta^{34}\text{S}$ analyses on the human samples are presented in Table 4 together with Figs. 10 and 11. $\delta^{34}\text{S}$ values for the human samples ranged between 12.1 and 16.7‰, with a mean of $13.3 \pm 1.7\text{‰}$. Five of the individuals displayed relatively homogenous values ranging between 12.1 and 13.1‰, with a mean of $12.7 \pm 0.5\text{‰}$, whereas the sixth individual (individual 5) had a markedly higher $\delta^{34}\text{S}$ value of 16.7‰. This might indicate a different geographical origin for this individual, although it could also be the result of a high input of harp seal into the diet. $\delta^{34}\text{S}$ values for the homogenous group of individuals are about 1–2‰ (i.e. within the margin of error) lower than the mean value for the ringed seals, possibly indicating that this seal species played a more dominant part in the diet of these individuals than in that of individual 5. It should be noted that the $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values of individual 5 do not deviate from other human values, and the data on these two isotopes thus indicate a similar diet for all individuals. Regarding individual 13, only the pool of the first and second molar displayed an acceptable C/S ratio and sulphur content. The $\delta^{34}\text{S}$ signature of the teeth correlated with values for the other individuals, with the exception of individual 5.

Radiocarbon dates

Uncalibrated radiocarbon dates analysed in this study are presented in Table 5. Calibrated dates (all dates are calibrated using

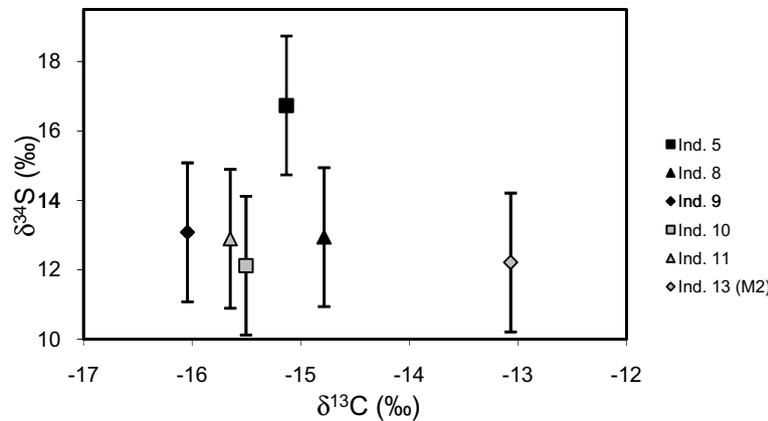


Fig. 11. Plot of isotopic $\delta^{13}\text{C}$ and $\delta^{34}\text{S}$ values for the human samples from Korsnäs. Error bars marking the 95% confidence level are applied for $\delta^{34}\text{S}$. Precision (95% confidence level) is $\pm 0.15\text{‰}$ for carbon, $\pm 2\text{‰}$ for sulphur.

Table 5

Results of the radiocarbon dating of samples from Korsnäs

Species/ind. no.	Lab ID	^{14}C lab ID	^{14}C BP	$\delta^{13}\text{C}$ (‰) ^a
Alces	KOR 02	Ua-32323	4365 ± 40	-21.8
Ursus	KOR 35	Ua-32325	4145 ± 40	-20.0
Sus	KOR 18	Ua-32324	4275 ± 40	-21.3
Canis	KOR 37	Ua-32326	4380 ± 45	-13.7
Ind. 5	KOR 44	Ua-33814	4465 ± 55	-16.7
Ind. 8	KOR 50	Ua-32327	4470 ± 45	-14.8
Ind. 9	KOR 51	Ua-32328	4320 ± 45	-16.0
Ind. 10	KOR 52	Ua-32329	4460 ± 45	-15.5
Ind. 11	KOR 53	Ua-32330	4540 ± 45	-15.7
Ind. 13	KOR 69	Ua-32331	4520 ± 45	-13.8
Ind. 14	KOR 70	Ua-32332	4275 ± 45	-15.2

^a $\delta^{13}\text{C}$ values obtained in connection with the radiocarbon dating. These might deviate from IRMS isotopic values, and will not be considered further.

OxCal v. 3.10, Bronk Ramsey 2005, see Fig. 12) for the terrestrial animals ranged between 3100 and 2580 cal. BC (2σ), largely corresponding to the second half of MN A. Only the brown bear sample displayed a date possibly falling within the beginning of MN B. The human and dog samples were calibrated with the reservoir correction of 70 ± 40 years established for the Middle Neolithic on Gotland (Eriksson, 2004, Fig. 11). With this correction the dates for the dog and human samples fell within the interval 3350–2640 cal. BC (2σ), correlating to the middle of MN A, with the exception of individual 14, who might date to the initial phase of MN B.

Discussion

Chronology

It is possible that the age offset caused by the reservoir effect is more extensive than the estimated correction for Gotland, but in the absence of bones with varied $\delta^{13}\text{C}$ values from closed contexts in the Korsnäs material this cannot be tested. However, it is highly unlikely that the dates from the terrestrial animals are all contemporary, and the data clearly shows that regardless of the extent of the reservoir effect, the Korsnäs site was utilized more or less continuously for several hundred years during the Middle Neolithic.

A reservoir correction of 70 ± 40 places the Korsnäs bones, with a high probability, within MN A.

PWC diet

In order to reconstruct the dietary pattern of the Korsnäs individuals a graphic model is employed, where $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values

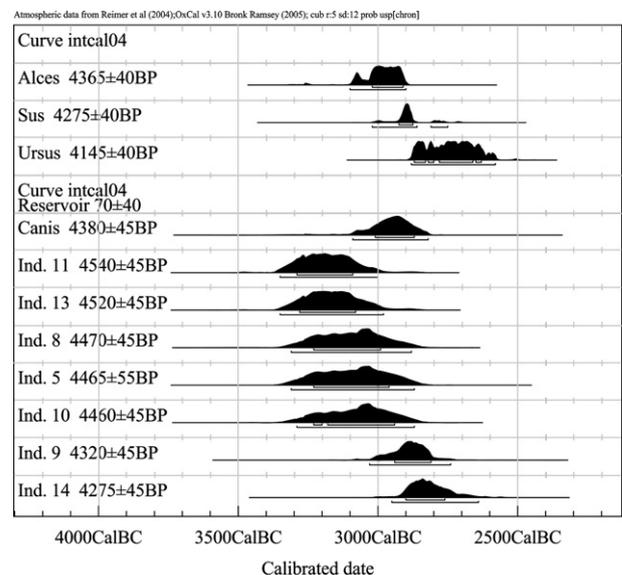


Fig. 12. Calibrated radiocarbon dates (OxCal v. 3.10). A reservoir correction of 70 ± 40 years (curve intcal04) is applied to the human samples and the dog sample, all with marine diets. The correction is established for the Middle Neolithic on Gotland by Eriksson (2004).

from humans, dogs and otters (representing fish eaters) are plotted against the isotopic predicted values for four potential groups of food sources (Fig. 13). The distributions of stable isotopes values for the moose/hare, pig, seal and fish are plotted with the corresponding trophic-level differences taken into account, i.e. $+3\text{‰}$ for $\delta^{15}\text{N}$ and $+1\text{‰}$ for $\delta^{13}\text{C}$. An individual with a protein input based entirely on one of these groups will display $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values within the group's predicted values, whereas an individual with a mixed two-component diet will plot somewhere between the two fields (cf. Eriksson, 2004; Schwarcz, 1991).

It is evident from Fig. 13 that the predominant protein component in the diet of all sampled humans originates from marine animals, and that the proportions of terrestrial faunal species in the diet are negligible. All individuals, with the exception of individual 13, plot within the predicted field for seal consumption. The anomalous $\delta^{13}\text{C}$ values for the three samples from individual 13 might suggest a large intake of fish in addition to seal. $\delta^{13}\text{C}$ values for individual 13 correspond to the predicted values for herring consumption, although the $\delta^{15}\text{N}$ values rather indicate a diet one trophic level above potential consumers of herring. Further, none of

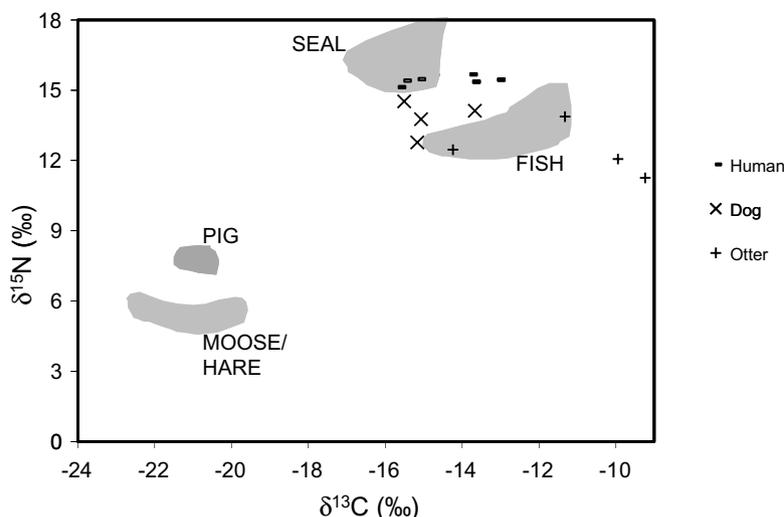


Fig. 13. Predicted values for individuals feeding off different protein sources, and observed isotopic values for human, dog and otter samples. Grey fields represent Korsnäs faunal isotopic values for groups of potential food sources, with the corresponding trophic-level differences taken into account, i.e. +1‰ for $\delta^{13}\text{C}$ and +3‰ for $\delta^{15}\text{N}$. Precision (95% confidence level) is $\pm 0.15\%$ for both carbon and nitrogen.

the human samples have a diet similar to that of the otters. Analysis of the intra-individual dietary pattern for individual 7 and 13 indicate only small-scale dietary changes, none of which can be attributed to any temporary input of terrestrial protein into the diet. Conclusively, the people from Korsnäs, in analogy with the Pitted Ware people on the Baltic islands, were predominantly seal hunters, and chose not to incorporate available terrestrial animals into the diet to any large extent.

The animal bones deposited on the Korsnäs site emanate mainly from seal and pig, although since a coarse-meshed sieve was used during excavation (Olsson et al., 1994), the proportion of fish was probably more extensive than the recovered bone assemblage indicates. Based on the relative proportions of faunal species on the site, Aaris-Sørensen (1978) suggested an economy where wild boar and seal, together with large amounts of fish, made up the main food sources. The method of reconstructing subsistence patterns from the faunal assemblage has further been applied to several PWC sites (Ekman, 1974; Ericson and Forendal, 1980; Hårding, 1996; Ridderstråhle, 1979). It is evident from the stable isotope analysis on the Korsnäs material that this approach can be questioned, since the dietary practice does not correspond to the proportions of deposited animal bones.

Detecting cultural contacts

Due to the fact that the PWC people on the Baltic islands as well as on Korsnäs based their diet on marine resources, it is problematic to identify potential contacts and movements between different PWC groups on the basis of $\delta^{34}\text{S}$ data. Marine sulphur isotope values are likely to be similar on the Baltic coast and on the islands. Minor differences in the $\delta^{34}\text{S}$ signatures might be the result of consumption of migrating harp seal, and this could be the case with individual 5. The isotopic data from Korsnäs can confirm that the PWC dietary strategies were the same throughout the Baltic islands and on the west side of the Baltic, but the question of if and how people interacted within this region remains to be answered.

It is interesting to note that the individual with the highest $\delta^{13}\text{C}$ values, individual 13, deviates in other ways as well. The mandible of this individual was accompanied with burial gifts in the grave, where an eastern influence is indicated by the presence of a curved chisel. The special treatment of this individual, together with the deviating isotope signature, might indicate that the individual

was not originally from Korsnäs. It is also possible that the meanings associated with this inhumation differ from those of other burials on the site. Only the mandible of the individual seems to have been deposited, together with an assemblage of other objects not necessarily intended as burial gifts. It is evident that human remains were treated in a variety of different ways on the Korsnäs site as well as in many other PWC contexts.

The PWC pigs

The question of whether or not the Pitted Ware people kept domestic pigs is debated in Scandinavian archaeology. The main focus has been Gotland, where large terrestrial mammals are not indigenous, and where the earliest pig remains are dated to the Early Neolithic (Lindqvist and Possnert, 1997). The fact that pigs were introduced by human agency during this period has been perceived as evidence of pig domestication by PWC people on Gotland (Jonsson, 1986; Lindqvist and Possnert, 1997). Österholm (1989) regards the presence of large numbers of pig mandibles in some PWC graves (as many as 23 mandibles have been recovered from one grave in Grausne, Stenkyrka parish) as evidence of domestication of pigs, since it would be impossible to hunt and kill such a high number of animals on one occasion. The Gotland domestication hypothesis has further been supported by, for example, Wallin and Martinsson-Wallin (1992) and Hedemark et al. (2000). A presence of domestic pigs has also been suggested for the PWC sites on the west side of the Baltic. Jonsson (1986) regards the correlation in size between the mainland Neolithic pigs and the Gotland specimen (perceived as domestic) as evidence for PWC pig domestication on the west side of the Baltic. Benecke (1993) identifies a division of the mainland Neolithic pigs into two morphologically different groups, where the smaller specimens are considered to be domestic, and age estimates on PWC pigs indicating a high frequency of young specimens (up to 2 years) are regarded as further evidence of domestication.

Rowley-Conwy and Storå (1997) strongly criticize the suggested presence of domestic pigs on Gotland, arguing that importing of wild animals to islands is known from other Neolithic contexts in Europe, and that occurrence of several mandibles in closed contexts is insufficient evidence of domestication, since the mandibles could have been hoarded from several individual kills over a longer period of time. They regard the pigs as wild, based on an identified seasonality pattern in the kill of the pigs that differs from the all-

year kill pattern of Neolithic domestic pigs in central Europe. It is further argued that there is no niche for domestic pigs regarding food, since agricultural waste products, which comprise the main food resource for domestic pigs, are absent on PWC sites. The discussion is continued by Rowley-Conwy and Dobney (2007), arguing that with respect to the currently available data (biometric evidence, stable isotope data etc.) the PWC pigs should be considered wild. Lepiksaar (1974) suggests that PWC pigs were wild boar which during cold winters fed on human food waste, in what can be regarded as an initial phase in the transformation from wild boar to semi-domestic outdoor pigs. A standard method of separating wild pigs from domestic ones is through third molar length measurements (Magnell, 2005; Welinder et al., 1998), a method through which Ekman (1974) interpreted the Gotland pigs as wild. However, separating wild boar from domestic pigs through osteometrics is problematic (Magnell, 2005; Rowley-Conwy, 1995; Rowley-Conwy and Storå, 1997), which implies the need for additional methods, where isotope analysis of diet can be of value. A major advantage of keeping domestic pigs is that the omnivorous and scavenging nature of the species enables them to act as refuse collectors, taking care of human food waste, and this may have favoured the choice of keeping pigs over other ungulates in prehistoric societies (Masseti, 2007). Since agricultural activities seem to be absent from PWC sites, the diet of domestic pigs in these contexts ought to include a large proportion of marine protein, reflecting the major protein source for the humans. As far as the Korsnäs pigs are concerned, no such influence can be identified in the isotopic signatures. Here, the species seems to have a homogeneous terrestrial, mainly herbivorous diet. This implies that the analysed pigs were wild or feral rather than domesticated. Similar isotopic data on pigs from Västerbjers and Ire on Gotland has been presented by Eriksson (2004), who interprets the animals as wild or feral. The isotopic data together with a lack of evidence supporting a domestication of pigs within the PWC imply that the PWC groups were occasional wild boar hunters rather than pig breeders.

Throughout history, few animal species have been so frequently associated with symbolic meaning as the pig, perceived as both abominable and sacred (cf. Harris, 1998; Simoons, 1967). Sacrificing/feasting of pigs is known from, for example, prehistoric Egypt, Mesopotamia and Greece (Hamilakis and Konsolaki, 2004; Simoons, 1967), and is accounted for in numerous anthropological studies, mainly concerning Polynesia and Melanesia. Pig festivals including sacrificing and consuming up to hundreds of pigs are known from Hawaii and New Guinea, where pigs often offer a small nutritional contribution, but are being hunted or bred for these occasions (Kirch, 2001; Oliver, 1989; Rappaport, 1984; Swain and Trompf, 1995; Valeri, 1985; Wiessner, 2001). Among some New Guinea groups, large pig kills are socio-political rather than ritual events, although pigs are occasionally sacrificed to restrain malicious supernatural forces (Sillitoe, 2007). Pig sacrificing among the Pacific islands is further often linked to ancestral cult (Akin, 1996; Rappaport, 1984; Swain and Trompf, 1995), or engaged upon in connection with, for example, purificatory rites (Akin, 1996), mortuary rituals (Williamson, 1933), in the advent of war or when praying for favourable weather (Swain and Trompf, 1995). In New Guinea, where the main sources of nutrients come from horticulture, many tribes keep pigs at varied degrees of domestication, whereas other groups have chosen not to engage in pig breeding activities. Hunting of feral pigs is conducted to a variable extent, and is mainly of small economic significance but ceremonially important. Among many tribes, two groups of pigs that are morphologically identical are distinctively culturally separated into wild and domestic pigs. Wild boar flesh can only be consumed at certain occasions, often separate from situations where the domestic pigs are being eaten (Rosman and Rubel, 1989). Pigs are frequent in Hawaiian cosmology, where one of the most popular mythical figures, the demigod Kāmpua'a is described

as half man, half hog (Beckwith, 1940). In Norse mythology, the cosmic boar Sæhrímnir resided in Valhalla, where he was killed and eaten each night and resurrected the following morning (cf. Ström, 1985). Among the Kubu tribe on Sumatra, wild pigs are believed to be deities called from their own realm by the shaman, allowing themselves to be hunted and eaten (Sandbukt, 1984). A common belief associated with hunting is that certain characteristics of an animal can be passed over to humans consuming its flesh. In the Rif mountains of Morocco, children are fed the flesh of wild boar in order to obtain some of the animal's strength (Moreno-García, 2004). Among Prehispanic Philippine societies, the vitality and spiritual power of a pig was believed to be transferred to the consumer of the pig's head (Junker, 2001).

It is evident from the stable isotope data that pork did not constitute a part of the everyday diet of the Korsnäs people. Nonetheless, pig remains comprise a large part of the bone assemblage from the site. Pig bones dominate even more at Västerbjers, Gotland, where the human diet, as in Korsnäs, was based on marine resources (Eriksson, 2004). It is possible that seals, constituting the main prey, were slaughtered and cut up on other locations, leaving parts of the skeleton behind, whereas hunted wild boar carcasses seem to have been handled at the settlement site. This would explain why seal is not clearly dominating the mammal bone assemblage, but the question still remains of how to understand the large number of pig bones. Pigs do not seem to be more frequent than other mammal species among the bone/antler artefacts at Korsnäs, which is why the pig bones cannot be explained solely by means of production raw material. However, pork might have been consumed on certain occasions, rare enough not to be detectable in the isotopic data. Could feasting and sacrificing of wild boar be a ritual aspect of the PWC? Such activities would include bringing at least some animals to the site as intact carcasses, and bones from sacrificed and consumed boars might have been intentionally deposited within the settlement area. Since PWC settlement sites often include remains from burials and other ritual activities, potential feasts and sacrifices might very well have taken place within these areas as well. The spatial distribution of pig bones could provide valuable information regarding possible feasting/sacrificing activities, but unfortunately this cannot be reconstructed at Korsnäs where the surface layers have been disturbed and a large part of the bones are recovered from the dump heaps.

Pig mandibles, tusks and tooth beads are common features in PWC graves on Gotland (Ekman, 1974; Janzon, 1974), indicating that the wild boar held a prominent position within the cosmology. Grave goods are very rare on Korsnäs and do not include remains of pig, but beads and pendants of boar tusks and teeth have been identified from the site (Sjöling, 2000). A possible parallel can be found in New Guinean societies, where it is common to keep the jaws of hunted pigs as trophies (Rosman and Rubel, 1989). This proposed incorporation of wild boar in the cosmology, including sacrificing and ritual consumption of the animal, is in line with the apparent hunting-gathering identity of the PWC people. Even though fish is far more nutritionally important than meat in almost all hunter-gatherer societies in modern time (Anderson, 2005), the identity as hunters is known to be very central, and successful hunters are held in high esteem (e.g. Oliver, 1989; Rosman and Rubel, 1989). A prehistoric example of this phenomenon has been identified on the Mesolithic/Neolithic site Zvejnieki, Latvia, where stable carbon and nitrogen isotope data indicate a diet consisting mainly of freshwater fish, whereas the grave goods emphasize big game hunting (Eriksson et al., 2003).

PWC and identity

The suggested common identity within the PWC groups on the islands and west side of the Baltic seems to manifest itself in sev-

eral ways. The remarkably uniform marine diet, evident in the isotopic data, indicates a powerful ideological emphasis on seal hunting. The hunting identity is also manifested in the implied prominent position of the wild boar in the cosmology. There are puzzling differences though, such as the fact that the rich burial material of the Baltic islands has no parallel on the west side of the Baltic. Korsnäs is one of very few PWC sites on the west side of the Baltic that includes evidence of burials. It is possible that the rituals connected with death and burial were one of the not so uniform aspects of the Baltic PWC groups, or perhaps the PWC graves on the west side of the Baltic remain to be uncovered.

The seal is not at all as frequent as the boar in the PWC burial contexts on the Baltic islands, but the animal is represented, for example, in the shape of tooth pendants and female skirts made of seal teeth (Janzon, 1974). At the Ajvide burial ground on Gotland, an area impregnated with seal train-oil has been interpreted as a seal altar, where the animals were handled in connection with burial rituals (Österholm, 1997). At the site Jettböle on the island of Åland, evidence for a selective handling of seal skulls together with a figurine interpreted as representing a merge of anthropomorphic and seal characteristics (Storå, 2001) present further indications of the cosmological significance of seals within the PWC. It seems as if the seal and the wild boar played somewhat different parts in the hunting identity of the PWC people, but the cosmological importance of both species is evident.

Conclusion

Isotopic data, together with the archaeological material concerning the PWC, reveal an ideology that clearly deviates from the Neolithised concepts of agriculturalism/pastoralism. Results presented in this study, together with data from other PWC sites in the Baltic region, present evidence that the coast and the sea prevailed within this cultural sphere not only symbolically but also economically. The PWC in the Baltic region existed as a common hunting identity, manifested on an economic level in the exploitation of marine resources, and on a cosmological level in the prominent position of the seal and the wild boar. Domestic animals only included dogs, and the emphasis on the wild was manifested through occasional boar hunting, possibly followed by ritual feasting off the hunted prey. Apparently, the Neolithisation process was not all embracing, and the Pitted Ware People around the Baltic were, in all aspects, wild at heart.

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