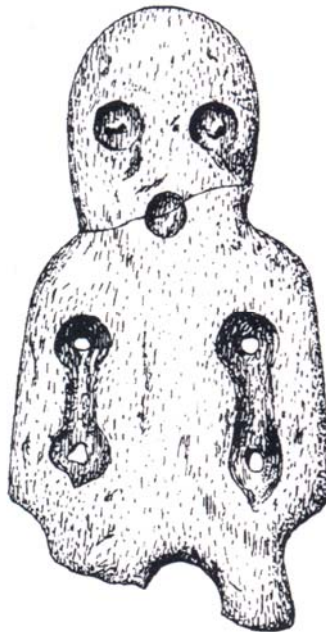


The Wild Side of the Neolithic

A study of Pitted Ware diet and ideology through analysis of stable carbon and nitrogen isotopes in skeletal material from Korsnäs, Grödinge parish, Södermanland



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Abstract

The Pitted Ware Culture site Korsnäs in Södermanland, Sweden presents a, for the region, unique amount of preserved organic material suitable for chemical analyses. Human and faunal skeletal material has been subjected to stable isotope analysis with the aim of examining whether the diet of the Korsnäs people correlates with the seal-based subsistence of Pitted Ware Culture groups on the Baltic islands. Further, the relationship between the faunal assemblage and the human diet has been studied, and the debated question of whether the Pitted Ware people kept domestic pigs has been addressed. Ten new radiocarbon dates are presented, which place the excavated area of the site in Middle Neolithic A, with a continuity of several hundred years. The results show that the diet of the Korsnäs people was predominantly based on seal, and seal hunting was probably an essential part of the Pitted Ware Culture identity. Based on the dietary pattern of the species, it is argued that the pigs were not domestic. The faunal assemblage, dominated by seal and pig bones, does not correlate with the dietary pattern, and it is suggested that wild boar might have been hunted and sacrificed and/or ritually eaten on certain occasions.

Cover illustration: Anthropomorphic bone/antler figurine from Korsnäs. From Olsson *et al.* 1994, front page.

Tack

Stort tack till Jan Storå för all hjälp med sampling av material samt konstruktiva diskussioner och kommentarer. Tack Kjell Persson för hjälp med kartframställning och krånglande dataprogram, och tack Cajsa för språkgranskning av otaliga utkast under skrivandets gång.

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Early and Middle Neolithic “cultures” in Eastern Middle Sweden

PWC	Pitted Ware Culture
FBC	Funnel Beaker Culture
BAC	Battle Axe Culture

Neolithic periods and occurrences of the different “cultures” PWC, FBC and BAC in Eastern Middle Sweden, as presented in Edenmo et al. 1997

EN	Early Neolithic	4200-3300 BC	
EN I	Early Neolithic I	4200-3650 BC	FBC
EN II	Early Neolithic II	3650-3300 BC	FBC + PWC
MN	Middle Neolithic	3300-2350 BC	
MN A	Middle Neolithic A	3300-2700 BC	PWC
MN B	Middle Neolithic B	2700-2350 BC	PWC + BAC
LN	Late Neolithic	2350-1800 BC	BAC



Fig. 1. Map of Korsnäs and other sites discussed in the study. 1 – Korsnäs, 2 – Jettböle, 3 – Åloppe, 4 – Äs, 5 – Häggsta, 6 – Överåda, 7 – Åby, 8 – Alvastra, 9 – Ire, 10 – Västerbjers, 11 – Ajvide, 12 – Köpingsvik.

1. Introduction

1.1 Preface

The sites and artefacts assigned to the Pitted Ware Culture (PWC) of the Early and Middle Neolithic in Scandinavia are of a complex and enigmatic nature. Several attempts of defining, categorizing, explaining and trying to understand this heterogeneous group of people have been made, but still a lot of questions remain unanswered. The considerable regional variation within this “culture” implies that the PWC, rather than to be considered an entity, must be understood as a set of differing ideologies with a few uniting features. The focus in this study, the Pitted Ware site of Korsnäs on Södertörn, Södermanland, Sweden will therefore be analysed in an Eastern Middle Sweden/Baltic context. The site is, to this date, the only one on the Eastern Middle Sweden mainland where the preservation conditions allow for chemical dietary analysis on PWC bone material. This study focuses on the everyday diet of the Korsnäs people, as compared to the osteological and dietary records from contemporary sites. PWC dietary practices on the Baltic islands seem heavily interwoven with notions of ideology and identity, with an everyday diet consisting almost exclusively of seal (e.g. Eriksson 2004). Is this the case for the Korsnäs people as well? Since Södertörn during the Middle Neolithic was an island in the inner archipelago, the environment presented a satisfying amount of marine resources as well as possibilities for inland big game hunting (Olsson *et al.* 1994:53). The dietary analysis can hopefully tell whether the Korsnäs people included all available food resources in their diet, or if there was a selection that must be understood in non-economical terms, such as ideology and identity.

There exists a paradox relationship between the identified faunal bone material and the dietary evidence from PWC sites on Gotland, where the animal element of the everyday diet does not coincide with the assemblage of dominating species in the archaeological record on the sites (Eriksson 2004). Could this be the case for Korsnäs as well? A significant amount of pig bones has been identified on the site. It has been suggested that the PWC people were pig herders (e.g. Österholm 1989:192, Welinder *et al.* 1998:183), a view that has been questioned by e.g. Eriksson (2004). Dietary evidence from humans and pigs might show whether the pigs from the Korsnäs site are wild or domesticated, and to what extent they were part of the human diet.

This study is based on the presumption that the dietary practice is of ideological significance, and that there is a relationship between diet and identity within the PWC. The Pitted Ware Culture is understood as a variety of groups and strategies, where the uniting features are the ideological emphasis on hunting-fishing-gathering and a conscious dissociation from the farming ideology of the Funnel Beaker Culture (FBC) and the Battle Axe Culture (BAC). That is not to say that no Pitted Ware group has ever cultivated the land. There do not seem to have been any absolute, widespread taboos concerning production and consumption of cerealia (Edenmo *et al.* 1997:180p). The dietary practice is viewed as one of many aspects of the large-scale hunting-fishing-gathering, non-farming ideology. The question is whether this particular aspect is locally expressed, or if there is a regional, homogeneous Pitted Ware diet.

1.2 Aim and problems

This study focuses on the dietary practice of the people from Korsnäs, derived from analyses on the skeletal remains. The relationship between the osteological faunal record on the site and the dietary analyses will be examined, in order to try to understand the dietary practice and its ideological meanings. Furthermore, the Korsnäs material will be compared with contemporary sites in Eastern Middle Sweden and on Åland in an attempt to provide an economical and ideological setting in which Korsnäs can theoretically be assigned a given place. The central problem is how the Korsnäs people have adapted to, and expressed, the large-scale PWC ideology. The starting-point is one of the identity-bearers that can actually, in part, be reached by the archaeologists, namely the conceptions concerning food.

The Korsnäs material, as well as the complex Pitted Ware Culture as a whole, inspire to a seemingly endless flow of questions, a few of which will be focused on here.

- How does the animal bone material on the site correlate to the everyday diet? How can this relationship be understood?
- What strategies concerning the adaptation to, and expressing of, large-scale PWC ideals can be identified in the dietary practice?
- What can the dietary analysis say about the nature of the pigs on the site? Are they wild or domesticated?
- Are there any differences in dietary practice between individuals, or on an intra-individual level, on the Korsnäs site? If so, how can these differences be understood? Are there any other distinguishable uniting features between individuals with similar diets?
- How do the faunal and dietary record on Korsnäs correlate to contemporary PWC sites in Eastern Middle Sweden and Åland?
- Do all the bone material in the graves and the cultural layer correspond chronologically to the PWC period? For how long, and when, has the site been habited/visited by PWC groups?

1.3 Material and methods

The focus of this study is the PWC site in Korsnäs, Grödinge parish, Södermanland. The preservation conditions on the site make dietary analysis on bone material possible, something that is not the case for any other documented PWC site on the Eastern Middle Sweden mainland. Selected bone and tooth material from the Korsnäs site will be subjected to dietary analysis. By measuring the proportions of stable isotopes of carbon and nitrogen extracted from bone and tooth collagen, information about the average protein intake can be obtained (De Niro 1985:806). In addition to the dietary analysis, six human and four animal individuals will be radiocarbon dated.

In the discussion, a comparative analysis will be performed, where the Korsnäs material will be discussed in an Eastern Middle Sweden/Åland PWC context. Similarities and differences in faunal assemblages and diet will be evaluated in an attempt to understand the Korsnäs site from a wider perspective. The comparative analysis will include contemporary PWC material from Eastern Middle Sweden and Åland (fig. 1). This region has been referred to as the classic area for the PWC (cf. Nygaard 1989:102, Wyszomirska 1984), and differs from the Southern and Western parts of the PWC area. The geographic definitions of this region vary with different scholars. In this study the area of interest, in the following referred to as the eastern region, includes the Swedish provinces Uppland, Västmanland, Södermanland, Östergötland, Öland and Gotland, as well as the Baltic island Åland. The specific areas selected for comparative analysis represent both inland, archipelagic and solitary island environments. Eastern region PWC sites that have previously been subjected to stable isotope dietary analyses are included in the comparison.

2. Background

2.1 The archaeology of the Pitted Ware Culture

2.1.1 *The Neolithic of Eastern Middle Sweden*

The transition between the Mesolithic and the Neolithic in Europe has been subject to extensive research and debate. The Neolithisation process has been described as a shift to a new way of life regarding economy, from hunter-gatherers to agriculturalist/pastoralists (e.g. Zvelebil & Rowley-Conwy 1984). A reverse view is the understanding of the process as the rise of an ideology and cosmology focusing on a symbolic domestication of the wild, where economic factors are viewed as secondary, subordinate to changes in mentality, and where monumentality is perceived as a structuring factor in the taming of the landscape (e.g. Hodder 1990, Thomas 1991).

The first phase of the Early Neolithic (EN I) in Eastern Middle Sweden displays several signs of

structural changes. Localities in the interior parts of the region become visible, presenting evidence of domesticated animals (sheep/goat and possibly pig), pottery and indications of agricultural activities. Ornamented pottery on these sites can be assigned to the Funnel Beaker Culture, a widespread Northern European complex associated with an agricultural ideology including distinctively ornamented pottery and megalithic tombs. With a few possible exceptions, in the Eastern Middle Sweden version of the Funnel Beaker Culture, the Vrå Culture (VRÅ), the monumentality aspect does not seem to be embraced and the coast continues to be utilized (Kihlstedt *et al.* 1997:112pp). During the second phase of the Early Neolithic (EN II), the coast again becomes a focal point, this time with the emergence of the Pitted Ware Culture. The known localities and finds indicate a co-existence of VRÅ and PWC material culture throughout EN II, after which there are no FBC finds North of Västergötland (Edenmo *et al.* 1997:192p).

During Middle Neolithic B (MN B), another set of artefacts appears in the archaeological evidence, assigned to the Battle Axe Culture, a 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 in the inland, often in a context with passage graves, whereas BAC settlement sites are invisible (Edenmo *et al.* 1997:135,186pp).

2.1.2 Pitted Ware Culture source material

The complex assemblage of material culture traditionally referred to as the “Pitted Ware Culture” appears in a wide area of Scandinavia in the Early and Middle Neolithic. The area that has been ascribed to this “culture” includes 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. The earliest appearances of Pitted Ware artefacts can be observed from Eastern Middle Sweden, and are dated to the second half of the Early Neolithic (Edenmo *et al.* 1997:136,183, Olsson, E. 1996b:441, Stenbäck 1998:94). In all of the regions mentioned the “culture” is present throughout the Middle Neolithic, and seems to disappear in connection with the transition to the Late Neolithic. In Eastern Middle Sweden and Åland it can possibly be dated to the Late Neolithic as well (Edenmo *et al.* 1997:182pp, Stenbäck 1998: 96). The PWC has traditionally been defined by the presence of three characteristic artefacts, namely 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 artifacts, as well as the time of appearance, between different regions (Nygaard 1989:102, Edenmo *et al.* 1997:152). Furthermore, it should be noted that all of these categories of artefacts also exist in other contexts that cannot be ascribed to the PWC (Edenmo *et al.* 1997:152).

In the western parts of the PWC area the settlements are characterized by the presence of flint tools, such as cylindrical cores and tanged arrowheads. The occurrence of Pitted Ware ceramic is uncommon (Edenmo *et al.* 1997:152pp). The eastern PWC region, on the other hand, displays large amounts of Pitted Ware pottery, but the frequency of flint tools is quite low (Edenmo *et al.* 1997:172pp, Welinder 1973:56). Regional differences in the archaeological evidence from the PWC area have made many researchers suggest a division of the Pitted Ware Culture into several groups, where the Eastern Middle Sweden region stands out as a distinctive area of its own (Edenmo *et al.* 1997, Nygaard 1989:102, Welinder 1973:56, Wyszomirska 1984:41p, Pappmehl-Dufay 2003:183). The Baltic islands Åland, Öland and Gotland can be included in this distinctive region, due to similarities in PWC material culture (Wyszomirska 1984:42). The rest of this chapter will deal with this eastern region.

The PWC in the eastern region is characterized by agglomerations of small groups of coast bound sites, traditionally interpreted as settlements. The sites often display large amounts of pottery and other artefacts, as well as occurrences of different constructions. These constructions are only rarely connected with huts or houses, but mainly consist of pits or diffuse dark coloured features (Edenmo

et al. 1997:172pp). According to Biwall *et al.* 1997, the total quantity of identified remains of building constructions in Eastern Middle Sweden at that time amounted to about fifteen, most of which can be described as small, rounded huts (Biwall *et al.* 1997:286). The total amount of known “settlement” sites in the same year was more than 200 (Edenmo *et al.* 1997:172).

Common artefacts on PWC sites are, besides the (often fragmentary) pottery finds, clay figurines, mainly of a zoomorphic character, and various axes, often of the double edged type. A small amount of tanged arrowheads are present at some sites, as well as slate tools (Edenmo *et al.* 1997:178p, Janzon 1983). Indications of agriculture on the sites are rare (Edenmo *et al.* 1997:180). The faunal material is dominated by seal bones followed by fish bones. Pig bones are represented in varied quantities, and dominate the faunal assemblage on some PWC sites. A few of the sites include human bone material, both scattered over the site and in the form of more or less evident graves, without above ground markers, and situated within the “settlement” area. The preservation conditions in the region are adverse due to sandy soils, which might explain the very sparse presence of organic material (Edenmo *et al.* 1997:180p Stenbäck 1998:98p).

The Pitted Ware pottery is generally classified and dated according to the Fagervik chronology, a typology of ornamental features compiled by Bagge (1951), based on pottery finds from the Fagervik site in Östergötland. Bagge divided the pottery ornaments into five chronological stages, Fagervik I-V, where the last phase has been ascribed to the Battle Axe Culture. Radiocarbon dates on adjacent organic material in closed contexts have placed the Fagervik groups I-IV in the Early and Middle Neolithic, and the different stages show a considerable chronological overlap (Edenmo *et al.* 1997:183p, Olsson, E. 1996b:441). It has been discussed whether or not Fagervik I and II belong solely to the PWC, or if these early ornamental features should be seen as representing a transitional phase between the Funnel Beaker Culture and the Pitted Ware Culture. The Fagervik phases II-IV coincide with Nermans similar pottery classification from 1927 into the Säter II-IV stages (cf. Edenmo *et al.* 1997:136, 169).

2.1.3 The Pitted Ware Culture on Södertörn

During the Early and Middle Neolithic Södertörn was part of an inner archipelago. The archaeological material implies that the island have been habited more or less continuously throughout the Mesolithic and Neolithic, the earliest settlements situated around 85 meters above shore level (m.a.s.l.) and dating back to ca 8500 BC (Pettersson & Wikell 2004:443pp). More than 30 known settlements on Södertörn can be assigned to the PWC, all of which are situated between 25-35 m.a.s.l (fig. 2). Korsnäs stands out as the only known PWC burial site in the area (Olsson, E. 1996b:43,56). The Battle Axe Culture on Södertörn is, apart from a few potsherds from Korsnäs (Werthwein 2002), only represented in one settlement site, and seems to be contemporary with the Pitted Ware material on that site (Olsson, E. 1996b:58).

The PWC settlement sites on Södertörn are mainly situated on steep, sandy slopes in close vicinity to the contemporary shoreline (Olsson, E. 1996b:44). Pottery constitutes the dominating

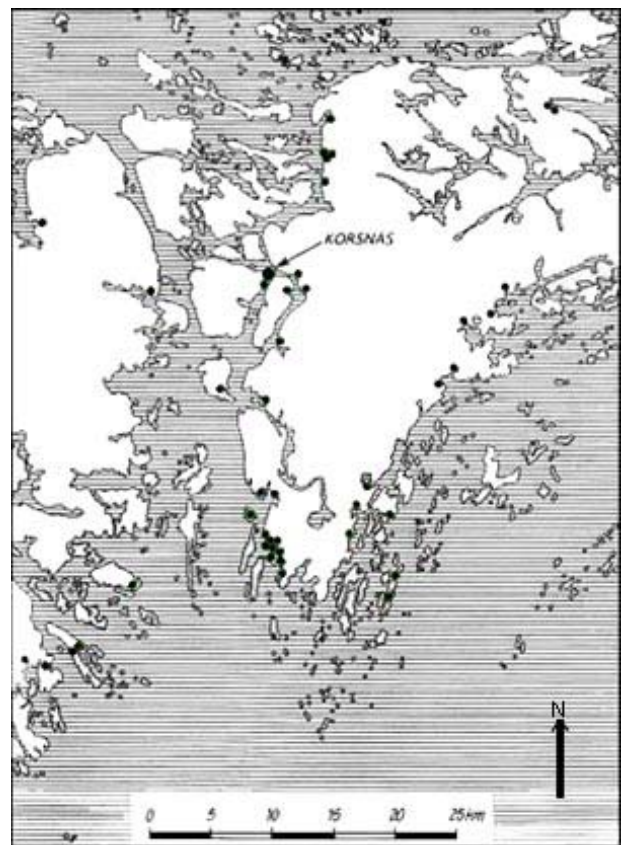


Fig.2. Södertörn with a shoreline 25 m. higher than today. PWC sites are marked. After Olsson, E. 1996b.

category of finds, and clay figurines as well as clay discs occur on many of the sites (Olsson, E. 1996b:46). Other finds consist of e.g. double egged axes, fragmented green stone axes, roundbutted rock/stone axes (Swedish *trindyxor*), flint arrowheads and slate artefacts. Bone artefacts are very rare, with all probability due to the adverse preservation conditions (Olsson, E. 1996b:46p). Neolithic hearths are absent on the sites. All the hearths that have been identified on the Pitted Ware sites have instead been dated to the Older Iron Age. Only a few indications of building constructions have been identified in the area, all in the form of remains of huts (Olsson, E. 1996b:44).

2.2 Previous studies

An early interpretation of the variations in the archaeological material in Scandinavia was that it represented the remains of different immigrated folk groups. Stenberger regarded the PWC as a coast bound ethnic group or tribe of Scandinavian or Eastern origin that immigrated to the PWC area during the Middle Neolithic. The people were originally seal-hunters and fishermen, but were of a practical, efficient and easily adaptable nature, and thus took up the art of farming when they came in contact with the FBC. They never became true peasants, though, and eventually moved on, allowing for the Battle Axe people to occupy the coast (Stenberger 1979:94-108). Other scholars viewed the PWC people as very primitive hunters and fishermen (Stjerna 1911, Schnell 1930).

With the development of the “New Archaeology” theories, new approaches to the definition of culture were presented, which focused on humans’ adaptation to nature (cf. Edenmo *et al.* 1997:135). Many scholars argued in favour of an enhanced focus on the economic factors when studying the PWC. Janzon accused the traditional definitions of culture of being insensitive and anachronistic, and proposed that since areas with similar economic structures are likely to develop similar social structures as well, an economic approach to archaeology should be preferred (Janzon 1983:18p). A lot of studies of the PWC have adopted this approach, where economic change is often closely linked to climate change (e.g. Malmer 1973, 2002, Welinder 1973, Welinder *et al.* 1998, Löfstrand 1974, Burenhult 1999). With this follows that the emergence of the PWC is mainly assumed to be the result of FBC/VRA groups adapting to new environmental conditions. However, it has been suggested that the PWC might instead have its roots in Mesolithic groups (Wyszomirska 1984:197pp, Åkerlund 1996:140, Malmer 2002:183). Burenhult explains the emergence of the PWC in the following way: The high exploitation of natural resources by the FBC in combination with a climate change led to a nutritional crisis, forcing the VRA culture people to adapt to new subsistence patterns, and to occupy new land. There were two ways of adjustment, where the local resources determined the subsistence strategies. Intensified cattle farming prevailed in the inland, leading to the emanation of the Battle Axe Culture, whereas the Pitted Ware Culture developed by the coast, with a mixed economy of fishing, seal hunting and pig breeding. The PWC peoples’ adaptation to the new economy led to new pottery forms, where the large vessels were provided with pits in order to keep them from breaking during the firing process (Burenhult 1999:318pp).

From the 1980:s onward, the strong focus on economic factors in archaeological research started to be challenged by some scholars, and the emphasis shifted to the active role of the material culture (e.g. Tilley 1982:55, Kihlstedt *et al.* 1997:122p, Gill 1998:77, Papmehl-Dufay 2003:181p, Larsson 2004:67). Critique was also put forward regarding the oversimplifying use of the term “culture” in the defining and categorization of the very diverse Neolithic society, and some researchers chose to adopt the term “tradition” instead (Tilley 1982, Andersson 1998:65). It was suggested that rather than searching for general patterns and common features, the diversity of the Neolithic material culture ought to be in focus, and a larger emphasis on regional sequences in the study of the PWC was proposed (Tilley 1982:55, Kihlstedt *et al.* 1997:85, Gill 1998:77, 2003). Economic factors were viewed as secondary, and the differences in material culture during the Neolithic were attributed to changes in ideology (e.g. Browall 1991:133pp, Olsson, E. 1996b:48, Kihlstedt *et al.* 1997, Andersson 1998:66, Carlsson 1998:48, Stenbäck 1998:89p).

A common view among archaeologists has been that the PWC emanated from the FBC, as a transition from a neolithicised farming ideology to a hunting ideology more in line with Mesolithic ideals. According to Browall (1991:136), the prerequisites for the development of the PWC lied in ideological and social changes within the FBC. Kihlstedt *et al.* (1997:122p) viewed the PWC as a group of people in the periphery of the FBC who adopted different strategies concerning economy as well as social and ideological relations. The material culture, rather than monuments, was the structuring factor in these new strategies, and it is regarded plausible that the Neolithic ideals never became incorporated into the PWC ideology. Stenbäck disagreed with this picture, arguing that Neolithic concepts introduced to the FBC, including knowledge of agriculture as well as changed perceptions of time and space, created a discrepancy between the world of ideas and the everyday lives of people who were still mainly hunter-gatherers in action and thought. The PWC is in this perspective viewed as an adjustment of this Neolithic concept, where agriculture and animal husbandry were probably maintained to some extent, but where the hunting identity was emphasized (Stenbäck 2003:194).

The relationship between the PWC and the BAC has been explained in a variety of ways, where two general hypotheses can be distinguished: the idea of different cultures or ethnic groups on the one hand (Tilley 1982, Knutsson 1995, Hallgren 1996, Larsson 2004), and an interpretation of varieties in material culture as representing different aspects of one culture or group (Carlsson 1991, Andersson 1998). Strinnholm (2001:123) rejected the notion of the PWC as a group of its own, and simply viewed the Middle Neolithic as a period of enhanced regional differences in material culture and economy.

The strong influence on the PWC from the Comb Ceramic area east of the Baltic has been stressed by many researchers (e.g. Welinder 1973:58, Wyszomirska 1984:198, Nygaard 1989:102p, Carlsson 1998:52, Stenbäck 1998:100). This influence is most apparent on Åland, where the PWC chronologically succeeds the Comb Ceramic Culture. The transition between the cultures has been interpreted as an enhancement of the maritime hunting identity within the local groups, where PWC ideals were incorporated (Stenbäck 1998:89p, 2003:201).

When defining the different cultures of the Early and Middle Neolithic in Scandinavia, economic factors have often been emphasized. The general view has been that while the FBC practiced farming and the BAC were herders, the PWC people chose a Mesolithic way of life, with a subsistence based on hunting, fishing, gathering and possibly pig herding (Tilley 1982:56, Wyszomirska 1984:197, Welinder 1987:104, Malmer 2002:178. Cf. Edenmo *et al.* 1997:136). A presence of domestic pigs on PWC settlements has been suggested by e.g. Österholm (1989:28). Welinder *et al.* (1998:183p) regarded the pig herd as a buffer resource in case the hunting would fail, or when large quantities of meat were needed for a feast. This general economic view has been criticized for being oversimplified (Strinnholm 2001:177p). The complete absence of farming activity on PWC sites has been questioned (Carlsson 1987:234, 1998:48, Gill 2003:113pp, Stenbäck 2003:194), as well as the idea of an FBC subsistence dominated by agriculture (Kihlstedt *et al.* 1997:112p). However, the importance of marine resources for the PWC in the eastern region is apparent. The seal is regarded to be of great importance, not only economically, but also symbolically, ideologically and mythically (Österholm 1997:478pp, Stenbäck 1998:100, 2003:201, Storå 2001:50p).

The coast bound areas of activity commonly referred to as PWC settlement sites are problematic to interpret, especially since there are few identified remains of building constructions. The prevailing theory has been that the areas represent settlements of a mobile community (Tilley 1982:58, Carlsson 1987:234, 1991:120, Knutsson 1995, Edenmo *et al.* 1997:175, Welinder *et al.* 1998:184). Knutsson argues that the mobility of the PWC is the basis of which we can understand the

differences between this group of people and the stationary BAC. Their two differing lifestyles make the PWC and the BAC essentially incompatible (Knutsson 1995:197p). Another interpretation of the coast bound sites is that they represent ritual places, where the close vicinity to the shoreline and the fragmented pottery are assigned significant value (Carlsson 1998:48pp). A deliberate fragmentation of pottery has been suggested (Andersson 1998:68pp, Carlsson 1998:48pp, Stenbäck 1998:101). Andersson identifies this fragmentarism not only in smashed pottery, but also in the presence of scattered skeletal remains and pieces of broken axes, and interprets it as symbolizing a collective ideal (Andersson 1998:68pp). The pottery has further been associated with hunting and fishing, both as having a practical function (Malmer 2002:179) and a ritual meaning (Åkerlund 1996:133). A ritual significance has also been assigned to the shoreline, which has been interpreted as a liminal place, marking the boundary between the living and the dead (Carlsson 1998:50p, Gill 2003:107,129pp).

3. The Korsnäs site

3.1 A history of the site

The Korsnäs site, RAÄ 447, is situated on the sandy slope of a ridge in Grödinge parish, on the north-western part of the Södertörn peninsula. Two lakes make up the site's natural boundaries to the north and south/south-west. The extension of the activity area has been estimated through phosphate surveying to ca 95,000 m² (fig. 3), topographically including levels between ca 18-50 m.a.s.l., with a higher frequency of finds in the interval 25-35 m.a.s.l. 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.* 1994:5pp, Olsson & Kihlstedt 2000:4p). According to shoreline displacement curves, the sea level during the PWC phase in the Mälardalen region was about 25-30 metres higher than today (Risberg *et al.* 1991:35, Olsson *et al.* 1994:8). 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 situated to the east. In this archipelagic environment, the Korsnäs site was strategically placed on a southern slope of an inlet (fig. 2. Olsson *et al.* 1994:8, Olsson & Kihlstedt 2000:5).

The site was discovered by Ivar Schnell in 1930 (ATA dnr 4197/30), and a phosphate survey followed in 1931 (Arrhenius 1931). A seminar excavation was executed in the south-western part of the site in 1933 by the Department for Nordic Archaeology at Stockholm University (ATA dnr 3683/33). A more extensive phosphate survey was conducted in 1944 (Arrhenius 1945). In connection with the planning of a gravel quarry in 1964, the upper layers of soil was removed from a ca 2000 m² large section on the south-west part of the site, damaging the cultural layer. This caused Stockholm University to engage in a rescue action, surveying 1250 m² of the damaged area and collecting exposed finds (ATA dnr 3347/64). In addition, an enhanced phosphate survey was performed in 1969 (Eriksson 1971). The soil removed 1964 was dumped in heaps, parts of which were sieved for finds by Grödinge hembygdsförening 1971-1972 (ATA dnr 3347/64). In 1970, the department for archaeological surveys (UV) at the National Heritage Board (Riksantikvarieämbetet, RAÄ) performed a survey aiming at investigating the damaged part of the site and determining the geographic limitations of the activity area. An area of 136 m² was excavated on levels between 29.0-37.3 m.a.s.l. (Olsson *et al.* 1994). A quaternary geological survey was performed by the Geological Survey of Sweden (SGU) in connection with the archaeological excavation, including a pollen analysis of a stratigraphic sequence in the Korsnäs peat bog, located ca 250 metres south-west of the excavation area (Miller & Robertsson 1981). Additional finds have been reported in connection with minor surveys of exploited ground by RAÄ/UV and as stray finds. In 2002, Stockholm County Museum engaged in a minor excavation in the south-eastern part of the site, ca 100 metres from the area damaged in 1964, where Battle Axe Culture potsherds as well as a pre-Roman Iron Age grave and two hearths were found (Werthwein 2002, see fig. 3).

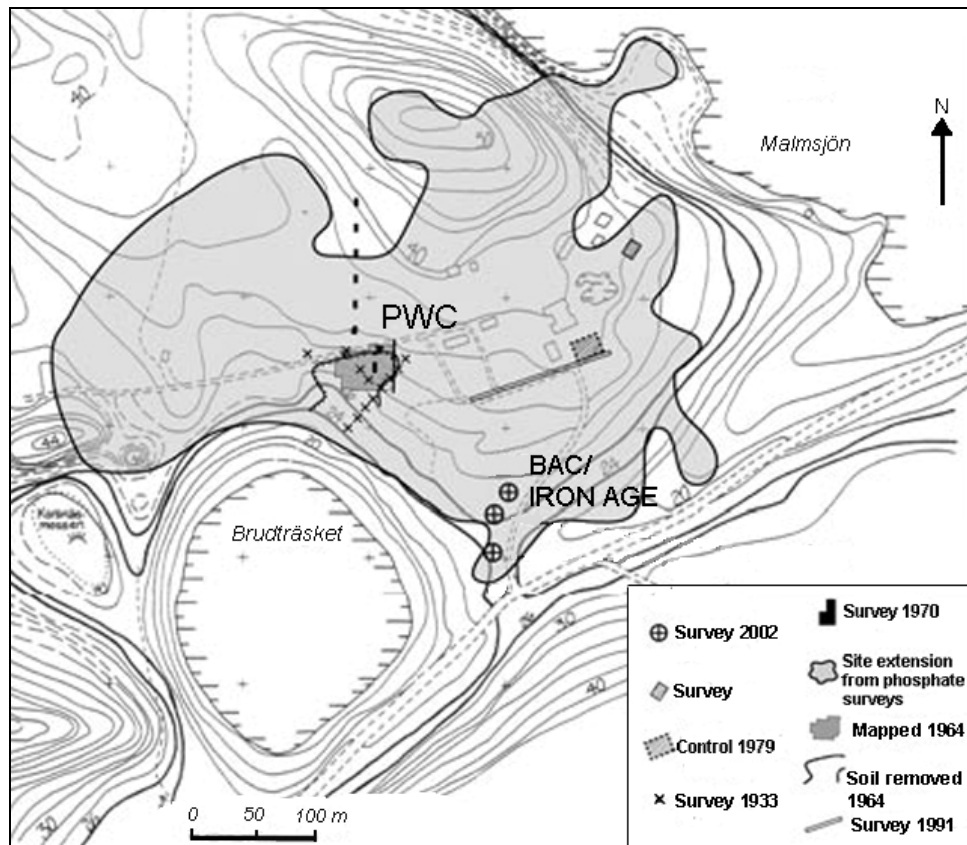


Fig.3. Map of estimated extension, previous surveys and occurring artefact assemblages on the Korsnäs site. Extension area is estimated from phosphate values $>100\text{P}^\circ$. Material analysed in this study originates from the area surveyed 1970 and the area mapped 1964. After Werthwein 2002.

3.2 The archaeological evidence

The Korsnäs artefacts mainly consist of pottery and stone tools, such as flakes, grinding stones, axes, arrowheads and chisels. The pottery in the south-western area of the site, which was excavated in 1970, is represented by the Middle Neolithic Fagervik III and IV series. The north-eastern area includes pottery with Early Neolithic Fagervik I, II and III features (Olsson *et al.* 1994:38,59). Other inorganic artefacts are ceramic figurines and clay beads. Furthermore, the Korsnäs site presents a number of bone/antler artefacts such as chisels, harpoons, points, anthropomorphic figurines and tooth beads.

The excavated area contained three definite and three possible graves (definite graves are defined as containing seemingly intentional deposits of human skeletal material, Olsson *et al.* 1994:20p), all without any visible constructions. These graves, situated between 31.3-32.3 m.a.s.l., were all completely or partially examined during the 1970 survey (fig.4). Other identified structures were pits and unexcavated hearths. No structures from building constructions have been found. In addition to the graves, human skeletal material was also found scattered throughout the cultural layer.

The animal bones found in 1970 have been subjected to osteological analysis by Kim Aaris-Sørensen (1978). Of the ca 17 kg animal bones, all but 325 g consist of unburnt material. Mammal bones make up 97% by weight of the analysed material. The number of identified specimens (NISP) and the minimum number of individuals (MNI) indicate a dominance of seal (*Phocidae*) and pig (*Sus scrofa*) among the mammal bones (table 1), and these two species, together with moose

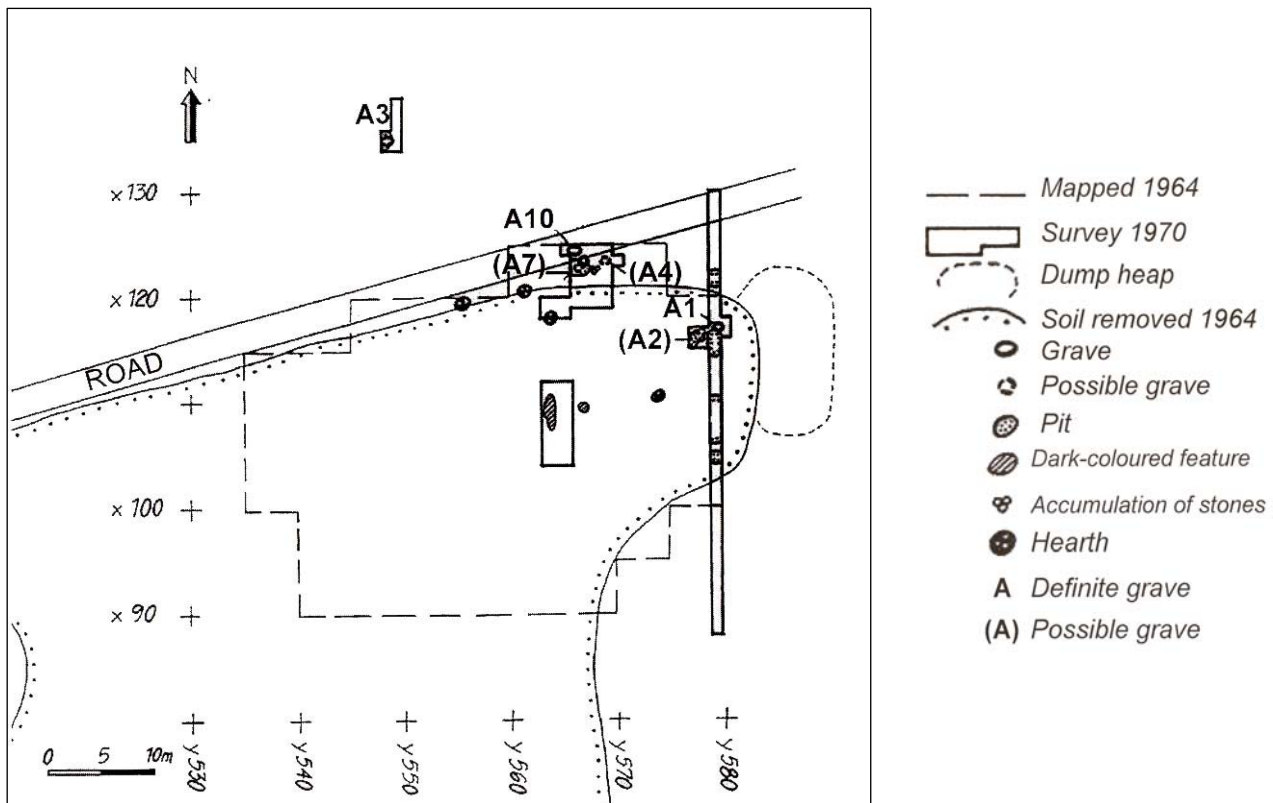


Fig. 4. Map of definite and possible graves, identified during the 1970 survey. Possible graves are put in brackets. After Olsson *et al.* 1994.

(*Alces alces*), dominate by weight. The seal bones are dominated by specimens of harp seal (*Pagophilus groenlandicus*), and fragments of ringed seal (*Pusa hispida*) and grey seal (*Halichoerus grypus*) have been identified in sparse numbers. The animal and human bones show a very varied degree of preservation. The south-western part of the site displays the highest frequency of preserved bones, together with very high phosphate values, causing Olsson *et al.* (1994:60) to argue for large-scale deposits of bone material in this particular area. In this way the soil would have become saturated with calcium, and thus the latest deposited bones were preserved.

Three radiocarbon dates were performed on bone material from the Korsnäs site in 1978 (table 2). The selected material, which came from a waste disposal pit, all consisted of bones from unidentified species, and several bones were pooled in each sample. The dates correspond to the Early Neolithic, Middle Neolithic A and possibly early Middle Neolithic B, where the earliest date stands out from the two later ones. In connection with the radiocarbon dating, $\delta^{13}\text{C}$ values for the samples were obtained. The principles of $\delta^{13}\text{C}$ (i.e. the relative proportions of the stable isotopes ^{12}C and ^{13}C in tissue) are discussed in section 4.2. Basically, the higher the $\delta^{13}\text{C}$ value, the more extensive is the input of marine protein in the diet. $\delta^{13}\text{C}$ values for the radiocarbon dated samples indicate a more marine input in the earlier date than in the two later ones (Olsson *et al.* 1994:39p and references therein).

The fact that the radiocarbon dates from 1978 were performed on several pooled bones from unidentified species makes the accuracy of the results difficult to assess. In general, terrestrial species are preferable when selecting material for radiocarbon dating, due to the marine reservoir effect. Since only the surface water in the oceans exchanges carbon with the atmosphere, water at deeper levels has lower concentrations of ^{14}C than the atmosphere. Upwelling water mixing with surface water causes the carbonates, which are taken up by living organisms, to become depleted in ^{14}C , thus exhibiting an apparent ^{14}C age. The extent of this apparent age varies depending on the basin's turnover time, and can in the large oceans amount to more than 1,000 years (Taylor *et al.* 1996:657). For the Baltic Sea, an estimated reservoir effect correction of 320 years has been

suggested (Olsson, I.U. 1996:117), though it has become clear that the complex natural history of the Baltic has caused the extent of the reservoir effect to fluctuate over time. The effect must therefore be calculated separately for any given period (Eriksson 2003:23). 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), though it is uncertain if these results can be applied to the Eastern Middle Sweden peninsula as well.

Table 1. Quantities per species of animal bones from the 1970 excavation at the Korsnäs site. MNI = Minimum number of individuals. NISP = Number of identified specimens. "Mammals, others" refers to identified species representing <0.1% of the total weight%. Data from Aaris-Sørensen 1978.

Species	MNI	NISP	Weight (g)	Weight %
Mammal (<i>Mammalia</i>), unidentified		8230	8408	49.5
Seal (<i>Phocidae</i>)	12	788	3047	17.9
Pig (<i>Sus scrofa</i>)	13	417	2256	13.3
Moose (<i>Alces alces</i>)	4	87	2187	12.9
Beaver (<i>Castor fiber</i>)	4	45	217	1.3
Dog (<i>Canis familiaris</i>)	7	46	122	0.7
Porpoise (<i>Phocaena phocaena</i>)	3	18	93	0.5
Roe deer (<i>Capreolus capreolus</i>)	2	8	39	0.2
Otter (<i>Lutra lutra</i>)	3	16	33	0.2
Bear (<i>Ursus arctos</i>)	1	3	19	0.1
Badger (<i>Meles meles</i>)	3	7	11	0.1
Lynx (<i>Lynx lynx</i>)	2	3	9	0.1
Hare (<i>Lepus timidus</i>)	4	9	10	0.1
Mammal , (<i>Mammalia</i>), others	10	11	6	0.0
Birds (<i>Aves</i>)	13	63	62	0.4
Fish (<i>Pisces</i>)	90	2746	481	2.8

Since the $\delta^{13}\text{C}$ value for the earliest radiocarbon date among the Korsnäs samples indicates a marine input, it is possible that the apparent ^{14}C date is older than the material's actual age. This could imply that the three samples are contemporary with each other. The uncertainty of the nature of the selected bone material makes the relation between the samples highly problematic to determine.

The location in a contemporary inner archipelago have caused Olsson *et al.* (1994:61) to interpret the Korsnäs site as a base camp, probably of a large size or utilised for a long period of time. Further, an all-year habitation, or at least continuous visits throughout the year, has been argued with regard to the varied animal bone material (Aaris-Sørensen 1978:21, Olsson *et al.* 1994:61). An economy based on hunting of seal, moose and wild boar together with fishing has been suggested, based on the faunal assemblage on the site (Aaris-Sørensen 1978:16, Olsson *et al.* 1994:60). Pollen analyses of sediments from the Korsnäs peat bog show no indications of agricultural activity, and only marginal human impact on the landscape (Miller & Robertsson 1981). The finds from the Korsnäs site correlate to a large extent with contemporary sites in Eastern Middle Sweden, but some differences can be distinguished. A Comb Ceramic Culture influence can be observed through

Table 2. ^{14}C -dates 1978, cal. after Reimer et al 2004; OxCal v. 3.10

Lab No.	BP-date	Calibrated date (1 σ)	$\delta^{13}\text{C}$
Lu-1285	4190±60 BP	2890-2670 cal BC	-20.8
Lu-1286	4270±60 BP	3010-2700 cal BC	-19.5
Lu-1287	4560±60 BP	3490-3100 cal BC	-17.9

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.* 1994:59).

4. Carbon and nitrogen stable isotope analysis

4.1 Introduction to stable isotope analysis

Stable isotope analysis of carbon and nitrogen provides information of an individual's dietary practice in terms of protein intake. The significance of the method is due to the assumption that “you are what you eat”, meaning that the isotopic proportions of $^{13}\text{C}/^{12}\text{C}$ and $^{15}\text{N}/^{14}\text{N}$ in tissue are influenced by the diet. Bone and teeth thus contain a dietary record, which can be traced and analysed (De Niro 1985:806, Ambrose & Norr 1993:1). While other archaeological methods of distinguishing prehistoric eating habits, such as analyses on faecal material, intestinal content and food crusts (cf. Schwarcz & Schoeninger 1991:284p), provide information about single meals, bone chemistry presents an insight into long term consumption patterns. As Eriksson (2003:13) has pointed out, stable isotope analysis can be separated from many conventional archaeological sources of information, in that it provides data that were not intentionally deposited. Furthermore, valuable information can be gained even in the absence of contextual data, as is the case for the scattered human bones on the Korsnäs site, though contextual information naturally is of major guidance in our understanding of the finds.

4.2 Carbon and nitrogen stable isotopes

An isotope is one of two or more forms of an element, which contain the same number of protons but have varying neutron numbers, giving them different atomic masses. The lighter elements usually have two stable isotopes, where the lightest one is the most common. The differences in atomic weight give rise to isotopic fractionation during chemical and physical reactions. There can also occur radioactive isotopes of an element. Atomic mass is measured in the unit *Dalton (Da)* (Pollard & Heron 1996:355pp).

Carbon has three different isotopes, the stable ^{13}C and ^{12}C , and the radioactive ^{14}C . The abundance of the carbon isotopes in the atmosphere is approximately ^{12}C :99%, ^{13}C :1% and ^{14}C : $10^{-12}\%$ (Pollard & Heron 1996:357). The ratio of ^{13}C to ^{12}C is expressed as $\delta^{13}\text{C}$ (‰) relative to the standard PDB (Pee Dee Belemnite, a South Carolina limestone), and can be calculated through the following formula (De Niro 1987:182, Ambrose 1990:435):

$$\delta^{13}\text{C} (\text{‰}) = \frac{R_{\text{sample}} - R_{\text{standard}}}{R_{\text{standard}}} \times 10^3$$

$R = ^{13}\text{C}/^{12}\text{C} \text{ ratio}$

A negative $\delta^{13}\text{C}$ value means that the sample is depleted of ^{13}C relative to the standard. $\delta^{13}\text{C}$ for atmospheric CO_2 is approximately -8‰ (Sealy 2001:270).

Terrestrial carbon isotope fractionation occurs during photosynthesis, when ^{12}C diffuses slightly faster than ^{13}C into the pores of leaves, causing an enrichment of the lighter isotope in the plant. Additional fractionation is caused by enzymes involved in the photosynthesis which select for ^{12}C . These processes result in a lower $^{13}\text{C}/^{12}\text{C}$ value in plants compared to the atmosphere (Chisholm 1989:12, Sealy 2001:270). There are three different pathways of photosynthesis resulting in plant categories with differing $\delta^{13}\text{C}$ values, namely C_3 , C_4 and CAM (Crassulacean Acid Metabolism) plants. In C_4 plant photosynthesis; selection for ^{12}C over ^{13}C is moderate, resulting in a mean $\delta^{13}\text{C}$ value of about -13‰. C_4 species include domesticated tropical grasses such as sugar cane, maize, sorghum and millet. In C_3 plant photosynthesis the discrimination of ^{13}C is extensive, resulting in a mean $\delta^{13}\text{C}$ value of about -27‰. Close to all native species in temperate climates such as Scandinavia are C_3 plants, for example trees, shrubs, legumes and vegetables. With this follows that all plants present around the Baltic during the Stone Age were C_3 plants. C_3 plants also include rice, wheat, barley and oat. CAM plants are capable of switching between the C_3 and C_4 pathways,

resulting in highly varied $\delta^{13}\text{C}$ values. They include succulents such as agave and cactus (van der Merwe 1989:112pp, Ambrose & Norr 1993:2p, Sealy 2001:270p). $\delta^{13}\text{C}$ values of animals are dependent on the food they eat. A large herbivore with a C_3 diet has a bone collagen $\delta^{13}\text{C}$ value $\sim 5\%$ more positive than the plants it consumes, i.e. about -22% . The shift seems to be less for smaller animals (Ambrose & Norr 1993:4pp, Sealy 2001:271). Furthermore, an increase in $\delta^{13}\text{C}$ with $\sim 1\%$ for each trophic level has been observed (Schoeninger 1989:40).

Marine plant isotope fractionation is a complex process, where dissolved carbon dioxide, bicarbonate and carbonate ions are involved in constant carbon exchange. Marine algae obtain carbon from bicarbonate, mainly through the C_3 pathway, but the C_4 cycle has been identified as well. The $\delta^{13}\text{C}$ values are further influenced by factors such as salinity and depth. The highly varied isotopic signatures in marine plants even out somewhat further up the food chain, and the estimated mean $\delta^{13}\text{C}$ value for marine animals in temperate oceans is -16% (Chisholm 1989:12p, Sealy 2001:271).

The influence of marine versus terrestrial resources in the diet can be interpreted in relation to approximated *end values*, approximated $\delta^{13}\text{C}$ values for an individual having a solely marine or solely terrestrial diet. A marine end value in the Baltic has been estimated to -14 to -15% , though the temporal fluctuations in salinity in the Baltic result in chronologically varying values. A terrestrial end value for Scandinavia has been approximated to -20 to -21% (Lidén & Nelson 1994:16pp).

Nitrogen includes two isotopes, ^{14}N and ^{15}N , both of which are stable. The natural abundance is ^{14}N :99.6% and ^{15}N :0.4% (Pollard & Heron 1996:357). The value of $\delta^{15}\text{N}$ is relative to the standard AIR (atmospheric N_2), and is calculated with the same formula as $\delta^{13}\text{C}$, where $R = ^{15}\text{N}/^{14}\text{N}$. Atmospheric nitrogen enters the biological systems via nitrification (nitrogen fixation) by soil microorganisms and bacteria, or via root systems in the form of nitrate or ammonium (De Niro 1987:184, Sealy 2001:272). Nitrogen is taken in by humans and animals in the form of protein. Through excretion of waste products depleted in ^{15}N , such as urea, $\delta^{15}\text{N}$ becomes enriched by approximately 3‰ for each step up the food chain, and this difference can be identified in archaeological contexts (DeNiro 1987:188, Schwarcz & Schoeninger 1991:999, Schwarcz *et al.* 1999:629). Since $\delta^{15}\text{N}$ of air is $\sim 0\%$, the value in plants is approximately 3‰, herbivores have $\delta^{15}\text{N}$ of $\sim 6\%$ and so on. Marine food chains are much longer than terrestrial ones, resulting in significantly higher $\delta^{15}\text{N}$ values for marine top predators compared to land-living carnivores (De Niro 1987:188, Sealy 2001:272). An increase in $\delta^{15}\text{N}$ can also be observed in breastfeeding individuals, who have values one trophic level up from their mothers (Fogel *et al.* 1989). In arid areas, very high $\delta^{15}\text{N}$ values have been observed. This phenomenon is presumed to be the result of animals under drought stress stimulating their water conservation through excessive excretion of urea depleted of ^{15}N (Schwarcz & Schoeninger 1991:299, Schwarcz *et al.* 1999).

4.3 Bone and teeth in dietary reconstruction

Bone consists of approximately 65% inorganic salts, mainly hydroxyapatite. The residual $\sim 35\%$ is built up by organic material, about 90% of which is composed of the protein collagen. Non-collagenous proteins, carbohydrates and lipids together make up $\sim 10\%$ of the organic material (Schwarcz & Schoeninger 1991:286, Fawcett & Bloom 1994:199pp). During a person's lifetime, bone is constantly being remodelled, resulting in a continuous conversion of the stable isotope signatures in the collagen. Isotopic data derived from bone thus represent the individual's average protein intake during several years prior to death. Collagen turnover rates in bone are complex, and tend to vary with age and between different skeletal elements, ranging over approximately 5-20 years, where compact bone has the slowest rate. Turnover time also increases with age (Lidén 1995:16, Lidén & Angerbjörn 1999).

Teeth are made up of three components: dentine, enamel and cement. The hard enamel makes up a protecting layer around the dentine in the crown, while the dentine root is covered by cement. Since enamel consists of ~95% inorganic material, mainly hydroxyapatite, it is not always adequately suited for stable isotope analysis, nor is the poorly preserved cement (Steele & Bramblett 1988:72, Schwartz 1995:152). The chemical properties of dentine are similar to those of bone, with the important difference that dentine (and enamel) is metabolically inert. With no collagen turnover, the isotopic composition is fixed at the time of tooth formation. Through studying both teeth and bone from an individual, intra-individual changes can thus be observed (Sealy *et al.* 1995:290p, Cox & Sealy 1997). Analyses of teeth formed at different ages have been applied in studies on breastfeeding and subsequent weaning (Lidén *et al.* ms).

4.4 Collagen extraction

Methods of collagen extraction aim to remove contaminants and other bone elements, such as lipids, non-collagenous proteins and hydroxyapatite, in order to prevent differing isotopic compositions from affecting the accuracy of the analysis (Ambrose 1990:432). Extraction of collagen is carried out according to the modified Longin method as presented in Brown *et al.* (1988), and can be summarized in three steps:

- Sampled bone powder is demineralised in a 0.25 M HCl solution for approximately 48 hours, after which the solution and inorganic material are removed through filtration.
- A solution of 0.01 M HCl is added and the sample is heated to 58°C for ~16 hours to dissolve the organic material.
- The dissolved organic residue is filtered through an ultrafilter, removing particles <30 kD. Particles >30kDalton are considered to be intact collagen chains, and thus, fragmented chains and humic substances are removed via the ultrafiltration.

The residual solvent is frozen to approximately -80°C, after which it is freeze dried and weighed.

4.5 Mass spectrometry

The basic principle of mass spectrometry is that electrically charged atoms and molecules, when passing through an externally imposed magnetic or electrical field, can be separated with regard to their mass-to-charge ratio. Since the isotopes of an element have different atomic masses, isotopic fractionation can be measured with this technique. Through combustion, the collagen becomes vaporised, after which it is injected into a vacuum system and bombarded by an electron beam, causing ionisation of the sample. The now positively charged particles are given a fixed energy through acceleration before they are transferred into the mass spectrometer in the form of an ion beam. The ion beam passes a bent, uniform magnetic field that causes the ions to deflect. The degree of deflection is dependent on the ion mass, where heavier ions are deflected less than lighter ones. Finally, the ions hit a collector system where the magnitudes of ions within the different deflection degrees are monitored (Pollard & Heron 1996:61pp).

The mass spectrometry analyses on the Korsnäs samples were performed at the Department of Geology and Geochemistry, Stockholm University. Between 0.4 and 0.6 mg collagen from each sample was combusted with a Carlo Erba NC2500 elemental analyser connected to a Finnigan MAT Delta+ isotope ratio mass spectrometer (IRMS). The precision was 0.15‰ or better for both $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$.

4.6 Collagen preservation and diagenesis

The substance collagen, in its strict biochemical sense, differs somewhat from the degraded ancient material used in dietary analysis (van Klinken 1999:687), though in this text the term collagen refers to both of these substances. A major problem with stable isotope analysis is the occurrence of collagen diagenesis, i.e., post-mortem chemical, physical or biological alterations disturbing the original isotopic signature. These processes are not primarily a function of age (De Niro 1985:808).

Collagen preservation is highest in compact bone (Gernaey *et al.* 2001:324). Isotopic signatures can be altered through heating, and stable isotope analysis can thus only be applied on unburnt material (De Niro 1985:808).

Studies on experimentally degraded bone have shown that soil microorganism invasion can alter the stable isotope ratio in protein. Microbial breakdown can cause a split of peptide bonds, resulting in an increase in the $\delta^{15}\text{N}$ signature with as much as one trophic level. Alteration of amino-acid composition can result in both increasing and decreasing $\delta^{13}\text{C}$ signals (Grupe *et al.* 2000:183). Further, microbial attack can cause collagen loss which, in turn, can lead to an increase in crystallinity (Hedges 2002:321pp). Additional factors affecting collagen preservation are changes in pH and soil ionic strength, also, in hot climates hydrolysis is a major problem (Gernaey *et al.* 2001:325). Even without interaction with exogenous molecules, a continuous degradation of collagen still takes place (van Klinken 1999:688). Collagen is best preserved in cold climates, such as Scandinavia, where microbial attacks are strongly reduced. Dry or anoxic environments are also preferable for collagen preservation. In a temperate environment with ideal burial conditions, collagen can survive for more than 100,1/000 years (Gernaey *et al.* 2001:323p).

4.7 Collagen quality indicators

Several methods can be employed to ensure that the collagen selected for analysis is sufficiently preserved, including control of carbon and nitrogen concentrations, C/N ratio and collagen yield, all of which can be evaluated through information gained during the extraction and measurement processes. Other techniques are available as well, but they require additional analytical steps, and were not employed in this study (cf. Ambrose 1990, van Klinken 1999). The visual appearance of the collagen can also be used as a quality indicator: a white, cotton-like structure implies that the sample is well preserved. Proposed acceptable collagen yields vary between 1% (van Klinken 1999:689) to 3.5% (Ambrose 1990:447) of the total sample weight. An acceptable collagen yield minimum of 1% is considered sufficient for the Korsnäs samples, provided that other criteria are fulfilled as well. The C/N ratio is another important collagen quality indicator. Van Klinken (1999:691) has suggested an acceptable C/N range of 3.1-3.5%, but stresses that this method is insufficient on its own. In this study, C/N ratios of 2.9-3.6 were considered to be free of contaminants, based on De Niro's (1985) comparison between prehistoric and modern bone. Modern analogues have also been used as a criterion of acceptable C- and N- concentrations, where the collagen is considered to be altered if concentrations fall outside the range 5.5-17.3% for nitrogen, 15.3-47% for carbon (Ambrose 1990:441).

4.8 Methodological concerns

It is important to bear in mind that the isotopic record of collagen represents protein input rather than overall diet. This can lead to an over-representation in the isotopic data of protein-rich food sources in cases of mixed economies. For example, land-derived food sources often include a significant non-protein component, as opposed to marine ones. If these two components are equally proportioned in the diet, the isotopic signature will indicate a mainly marine-based subsistence (van Klinken *et al.* 2000:50).

When ingested protein is incorporated into collagen, the protein $\delta^{13}\text{C}$ value is enriched to a varied degree, in large mammals about 5‰. The enrichment factor varies between tissues and between compounds within the tissue (Ambrose & Norr 1993:4pp, Sealy 2001:271). Further, the presence of lipids, carbohydrates, degraded collagen or other contaminants in the analysed samples can affect the accuracy of the isotopic data (Brown *et al.* 1988). To remove contaminants, the material selected for this analysis was therefore ultrasonically cleansed, and the outermost layer of the bone surface was removed before sampling. All laboratory work was carried out with the risks of contamination in mind. Ultrafiltration of the extracted collagen aimed at removing contaminating particles, and the mentioned collagen quality criteria were controlled. When possible, the same

skeletal element from every individual of a particular species was selected for analysis, since different parts of the body may yield varying isotopic signatures due to different turnover rates (Lidén & Angerbjörn 1999).

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 & Norr 1993:3). When studying material from the Baltic Sea, chronological fluctuations in $\delta^{13}\text{C}$ due to a complex natural history with varied salinity levels make the application of regionally approximated end values problematic. 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 & Lidén 2002, Eriksson 2003). On sites where faunal material is present, such as Korsnäs, baselines can be drawn from animal isotopic signatures. With isotopic data from potentially consumed animal species, expectancy values for individuals with specific diets can be anticipated (DeNiro 1987, Eriksson & Lidén 2002:6, Eriksson 2004:153).

4.9 Previous Neolithic dietary studies

The first stable isotope study on Scandinavian material was executed by Tauber (1981), who used $\delta^{13}\text{C}$ values to identify a sharp shift from marine to terrestrial resources between the Mesolithic and the Neolithic in Denmark. Since this study, the dietary research on the Northern European Stone Age has largely been focused on the Mesolithic-Neolithic transition, where two dichotomous views have crystallized. The idea of the Neolithisation as a widespread, rapid conversion from a marine-based subsistence to an agricultural way of life (e.g. Tauber 1981, Schulting & Richards 2002b, Richards *et al.* 2003a, 2003b) has been strongly criticized for being over-generalized and based on insufficient data (Lidén & Nelson 1994, Thomas 2003, Lidén *et al.* 2004, Milner *et al.* 2004, Barberena & Borrero 2005). A contradictory view has been presented, where the concept of a monolithic Stone Age is questioned, and where instead a rich diversity in dietary practices during the Mesolithic and Neolithic is suggested (e.g. Lidén 1995, Eriksson 2003).

Lidén (1995b:30) regards the dietary diversity during the Mesolithic and the Neolithic as related to location rather than culture or period, where the correlation between the PWC and marine isotopic signals is understood as a result of the coast bound locations of PWC sites. Eriksson (2003:28) argues that Mesolithic and Neolithic dietary practices were too diverse to fit in any general explanatory model. Dietary analyses from PWC contexts in the Baltic region have been performed on material from Jettböle, Åland (Lidén *et al.* 1995) Ire, Gotland (Lidén & Nelson 1994), and Västerbjers, Gotland (Eriksson 2004). The results all indicate a strong marine influence in the diet.

5. Selected samples

5.1 Human material

5.1.1 Tooth formation

Mineralisation of deciduous teeth is initialised in the womb, and the completion of crown formation for the different teeth follows in a sequence during the infant's first year of life (Lunt & Law 1974, Hillson 1996:189pp). The permanent molars form in a sequential order during childhood (Table 3. For a view of the dentition, see fig. 5). It is this sequential pattern of tooth formation that makes it possible to trace intra-individual changes in the diet during childhood, where deciduous teeth contain a record of the breastfeeding pattern (Wright & Schwarcz 1999, Lidén *et al.* ms).

Table 3. Average ages of completed crown formation in teeth. di₁, di₂ = first and second deciduous incisors, dc = deciduous canine, dm₁, dm₂ = first and second deciduous molars, M₁, M₂, M₃ = first, second and third permanent molars. Data on deciduous teeth from Lunt & Law 1974:605, permanent teeth: Hillson 1996: 189pp.

Permanent teeth		Deciduous teeth	
Tooth	Age (years)	Tooth	Age (months)
M ₁	3.0±1	di ₁	2.5
M ₂	7.5±2	di ₂	3
M ₃	13.0±2.5	dc	9
		dm ₁	5.5
		dm ₂	10

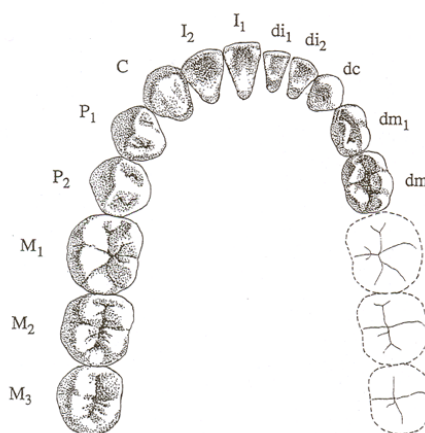


Fig. 5. A view of the dentition. Left: permanent teeth. Right: deciduous teeth. From Schwartz 1995:171

5.1.2 Human samples

Human material selected for stable isotope analysis represents both closed contexts and stray finds (table 4). From the graves, three individuals were selected for analysis, based on accessibility and degree of preservation. Samples were taken from both bone and teeth, in order to obtain as much information as possible from each individual. The same bone element, the mandible, was selected from all three individuals, together with the available molars. Grave 1 contained a child skeleton, and it was possible to sample deciduous teeth in an attempt to reconstruct the individual's breastfeeding and weaning pattern.

Grave 1 was situated underneath the cultural layer, and contained a well preserved child skeleton placed in crouched position with the head to the north-east. The age of the child was initially estimated to about 7 years (Olsson *et al.* 1994:69). Based on the eruption of the first molar, a younger age of 4-5 years is more probable (Storå pers. comm.). One small pottery fragment without ornaments was found close to the spinal chord (Olsson *et al.* 1994:69). Three deciduous teeth, dc, dm₁ and dm₂, together with the first molar were selected for analysis together with the mandible.

Grave 2 (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 metres to the south a dog cranium was found, together with tightly packed fish bones. A clay bead was placed in one of the eyes of the dog cranium (Olsson *et al.* 1994:69). The mandible, together with the first and second molar, was subjected to analysis. There was no formation of a third molar in the mandible. A sample from the dog cranium was analysed as well (lab no. KOR36).

Grave 3 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 representing Fagervik III with some Fagervik IV features (Olsson *et al.* 1994:70). Selected samples were M₁, M₂ and M₃, together with the mandible.

In addition to the individuals from the graves, human material found in the dump heaps sieved in

1971/1972 was selected for analysis. These bones are likely to have been scattered throughout the cultural layer. Initially, five humeri representing five different individuals were selected: three adults, one juvenile/adult and one child, older than the child in grave 1. Further, two mandibles with molars were included, in order to analyse the intra-individual dietary pattern. After collagen extraction it became clear that three of the five humeri had too low collagen yields to be included in the analysis. Only the child and one adult had an acceptable collagen yield. In order to obtain a higher minimum number of individuals, four femurs were subsequently included in the analysis. They represented one juvenile/adult and three adult individuals. The four femurs together with the child humerus all represent different individuals, and the minimum number of individuals for the no-context humans is therefore five. It cannot be ruled out that one of the femurs and the adult humerus represent the same individual. To distinguish between the individuals, they were all arbitrarily assigned a specific number prior to analysis.

Table 4. Human samples selected for stable isotope analysis. Elements in *italic* are excluded from mass spectrometry analysis due to low collagen yields.

Ind. no.	Context	Element	Age
ind. 1	Stray find	Humerus sin.	Adult, larger than ind. 2,3,4
ind. 2	Stray find	<i>Humerus dx</i>	Adult
ind. 3	Stray find	<i>Humerus dx</i>	Adult
ind. 4	Stray find	<i>Humerus dx</i>	Juvenile/adult
ind. 5	Stray find	Humerus dx	Child, older than ind. 14
ind. 6	Stray find	<i>Mandibula, M₁</i>	Adult
ind. 7	Stray find	Mandibula, <i>M₁, M₂</i>	Adult
ind. 8	Stray find	Femur sin.	Adult
ind. 9	Stray find	Femur sin.	Adult
ind. 10	Stray find	Femur sin.	Adult
ind. 11	Stray find	Femur dx	Juvenile/adult
ind. 12	Grave 3	<i>Mandibula, M₁, M₃</i>	Adult
ind. 13	Grave 2	Mandibula, <i>M₁, M₂</i>	Adult
ind. 14	Grave 1	Mandibula, dc, <i>dm₁, dm₂, M₁</i>	Child, 4-5 years

5.2 Faunal material

The diversity of animal species on the Korsnäs site makes it possible to establish thorough faunal reference values, with which the human dietary signals can be compared. Animal species from different levels in the marine and terrestrial food-web were selected for analysis. When possible, three individuals of each species were included, in order to obtain representative expectancy fields for the diet of the different species. A total of 48 samples from 15 species were included in the analysis. Six individuals of pig, representing different sizes, were sampled in order 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. Domesticated or semi-domesticated pigs are likely to have a more or less prominent input of human food disposals in their diet, whereas wild pigs display a terrestrial herbivorous to omnivorous dietary signal (Eriksson 2004:28). Further, four samples from dogs were analysed, including the cranium found in grave 2.

5.3 Samples selected for radiocarbon dating

Ten samples, representing both human and animal individuals, were selected for radiocarbon dating (table 5). The mandibles from graves 1 and 2 (individuals 13 and 14) were sampled, although the individual in grave 3 (individual 12) had to be excluded due to insufficient bone preservation. Further, the four human femurs were analysed in order to examine the temporal relationship between the graves and the cultural layer. Four terrestrial animal species were selected; moose, bear, pig and dog. In order to avoid any age discrepancies caused by the reservoir effect, no marine species were included in the analysis. All animal bones sampled were found during the sieving of the dump heaps, and thus lack contextual information.

Table 5. Samples selected for ^{14}C analysis.

Lab. no.	Ind. no.	Context	Species	Element	mg collagen
KOR 50	ind.8	Stray find	<i>Homo sapiens</i>	Femur	3.4
KOR 80,89	ind.9	Stray find	<i>Homo sapiens</i>	Femur	3.3
KOR 92,93	ind.10	Stray find	<i>Homo sapiens</i>	Femur	3.3
KOR 96,97	ind.11	Stray find	<i>Homo sapiens</i>	Femur	3.4
KOR 69,77	ind. 13	Grave 2	<i>Homo sapiens</i>	Mandibula	3.1
KOR 70,76	ind. 14	Grave 1	<i>Homo sapiens</i>	Mandibula	3.2
KOR 02		Stray find	<i>Alces alces</i>	Calcaneus	3.4
KOR 35,78		Stray find	<i>Ursus arctos</i>	Metatarsus	3.3
KOR 37,79		Stray find	<i>Canis familiaris</i>	Ulna	3.2
KOR 18		Stray find	<i>Sus scrofa</i>	Talus	3.3

6. Results

6.1 Stable isotope analysis

The bones selected for analysis proved to be of varied preservation. Collagen yields ranged between 0.2% and 10.0%. Sixteen samples, six animal and ten human specimens, were excluded due to insufficient collagen yields. These included all three cods (KOR 57, 58, 59) together with one specimen of pike (KOR 28) and two of beaver (KOR 05, 06), none of which displayed visible indications of poor preservation. The excluded human no-context material included three out of five humeri (individuals 2, 3 and 4), both of the samples (mandible and M1) from individual 6 and M1 of individual 7. Further, all four samples from the poorly preserved individual from grave 3 (individual 12) yielded insufficient amounts of collagen. Three samples had a collagen yield of 0.9%, i.e.. lower than the acceptable minimum of 1% as proposed by van Klinken (1999). Due to the visual appearance, together with the fact that they fulfilled the other quality criteria (C/N ratio, % C and % N, see further chapter 4), these samples were not excluded from analysis.

As a result of technical errors during the isotope ratio mass spectrometry (IRMS), data from five combusted samples were lost. Remaining collagen was used to rerun the samples. A specimen of pike (KOR 27) had only a low amount of collagen left (0.276 mg), and this could be the reason why the sample had a C/N ratio outside the acceptable range of 2.9-3.6 (DeNiro 1985). Two samples of harp seal (KOR 22,23) and one of ringed seal (KOR 21) were also dismissed due to high C/N ratios.

6.1.1 Faunal samples

The results of the stable isotope analysis on the faunal samples are presented in table 6 and fig. 6. The herbivorous species moose and hare have very low $\delta^{15}\text{N}$ values, ranging between 1.9‰ and 2.6‰. $\delta^{13}\text{C}$ values for four of the samples are similar (-22.0‰ to -20.7‰), with one specimen of moose displaying a somewhat deviating value of -23.2‰. The three specimens of marten, a terrestrial carnivore, have $\delta^{13}\text{C}$ values of -20.3‰ to -19.5‰, and $\delta^{15}\text{N}$ values ranging between 7.3‰ and 8.1‰.

Table 6. Carbon and nitrogen isotopic data for the faunal samples from Korsnäs. ~~Marked~~ samples are excluded since they fall outside quality ranges. * = radiocarbon dated individuals, ** = dog cranium found in grave 2.

Species	Common name	Element	Lab code	Bone/tooth (mg)	Collagen (mg)	Collagen (%)	$\delta^{13}\text{C}$ (‰)	$\delta^{15}\text{N}$ (‰)	% C	% N	C/N
<i>Alces alces</i>	Moose	Calcaneus sin	KOR 01	71.7	3.0	4.2	-21.8	1.9	44.1	15.2	3.4
<i>Alces alces</i> *	Moose	Calcaneus dx	KOR 02	67.7	4.1	6.0	-21.1	2.1	44.9	15.4	3.4
<i>Alces alces</i>	Moose	Calcaneus sin	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 dx	KOR 37	58.8	2.4	4.0	-13.7	14.1	42.2	15.5	3.2
<i>Canis familiaris</i>	Dog	Ulna dx	KOR 38	71.9	1.1	1.6	-15.2	12.8	38.6	13.8	3.3
<i>Canis familiaris</i>	Dog	Ulna dx	KOR 39	68.1	0.7	1.0	-15.5	14.5	35.3	11.9	3.5
<i>Castor fiber</i>	Beaver	Talus sin	KOR 04	71.4	0.7	1.0	-21.8	4.8	41.0	13.6	3.5
<i>Castor fiber</i>	Beaver	Talus sin	KOR 05	99.5	0.2	0.2	-	-	-	-	-
<i>Castor fiber</i>	Beaver	Talus sin	KOR 06	71.1	0.1	0.2	-	-	-	-	-
<i>Castor fiber</i>	Beaver	Talus dx	KOR 29	85.9	3.1	3.6	-21.3	4.4	42.4	15.6	3.2
<i>Clupea harengus</i>	Herring	Vertebrae	KOR 60	71.8	2.5	3.5	-14.4	10.0	42.2	15.5	3.2
<i>Clupea harengus</i>	Herring	Vertebrae	KOR 61	78.0	2.8	3.5	-13.8	9.2	42.3	15.7	3.1
<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 sin	KOR 26	39.0	0.7	1.8	-12.2	10.0	29.3	10.0	3.4
<i>Esox lucius</i>	Pike	Dentale sin	KOR 27	66.1	1.0	1.5	-12.7	13.7	42.3	13.4	3.7
<i>Esox lucius</i>	Pike	Dentale dx	KOR 28	55.0	0.3	0.6	-	-	-	-	-
<i>Gadus morhua</i>	Cod	Premaxillare dx	KOR 57	63.0	0.3	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>	Hare	Tibia dx	KOR 32	60.6	4.2	6.9	-22.0	2.2	42.6	15.5	3.2
<i>Lepus timidus</i>	Hare	Tibia sin	KOR 33	72.8	4.0	5.6	-20.7	2.4	42.7	15.7	3.2
<i>Lutra lutra</i>	Otter	Radius dx	KOR 10	89.2	8.2	9.2	-9.9	12.1	45.4	16.0	3.3
<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 sin	KOR 12	73.0	7.3	10.0	-14.2	12.5	45.8	15.7	3.4
<i>Lutra lutra</i>	Otter	Pelvis	KOR 30	57.4	3.0	6.4	-9.2	11.3	43.3	16.1	3.1
<i>Martes martes</i>	Marten	Humerus	KOR 07	58.8	5.1	5.2	-20.2	7.3	44.3	15.6	3.3
<i>Martes martes</i>	Marten	Humerus	KOR 08	60.8	5.7	8.7	-19.5	8.1	44.4	15.7	3.3
<i>Martes martes</i>	Marten	Humerus	KOR 09	59.2	4.1	9.4	-20.3	7.7	44.8	15.6	3.4
<i>Melanitta fusca</i>	Scoter	Coracoideum	KOR 54	59.2	4.9	7.0	-16.0	11.1	43.7	15.7	3.2
<i>Melanitta fusca</i>	Scoter	Coracoideum	KOR 55	61.3	1.3	8.3	-17.1	8.5	41.2	15.1	3.2
<i>Melanitta fusca</i>	Scoter	Coracoideum	KOR 56	73.5	4.7	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>Pagophilus groenl.</i>	Harp Seal	Temporale	KOR 22	71.7	1.1	1.5	-17.8	13.4	45.3	14.0	3.8
<i>Pagophilus groenl.</i>	Harp Seal	Temporale	KOR 23	70.1	0.6	0.8	-17.3	15.2	45.0	12.9	4.1
<i>Pagophilus groenl.</i>	Harp Seal	Temporale	KOR 24	80.0	1.9	2.3	-16.4	12.4	44.1	15.0	3.4
<i>Pusa hispida</i>	Ringed Seal	Temporale	KOR 19	115.1	1.1	0.9	-16.5	12.3	45.9	14.9	3.6
<i>Pusa hispida</i>	Ringed Seal	Temporale	KOR 20	75.7	1.5	2.0	-17.7	13.1	42.7	14.0	3.6
<i>Pusa hispida</i>	Ringed Seal	Temporale	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	87.5	3.2	3.7	-22.0	4.6	42.4	15.1	3.3
<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	77.6	5.5	7.1	-21.3	4.3	44.0	15.8	3.2
<i>Ursus arctos</i>	Bear	Metacarpus 3 dx	KOR 34	71.3	0.6	0.9	-20.2	3.9	35.7	12.7	3.3
<i>Ursus arctos</i> *	Bear	Metatarsus 3 dx	KOR 35	79.4	2.8	3.5	-20.0	3.8	41.7	15.5	3.1

The six samples representing pig, an omnivorous species with a wide range of habitats and (mainly vegetarian) food sources (Curry-Lindahl 1998:360pp), yield very similar values. $\delta^{13}\text{C}$ values range between -22.1‰ and -21.3‰, with a mean and standard deviation of -21.7 ± 0.3 ‰. For $\delta^{15}\text{N}$, values ranged from 4.3‰ to 4.8‰, with a mean and standard deviation of 4.6 ± 0.2 ‰. The values for the pigs are overlapped by 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' low $\delta^{15}\text{N}$ values, together with the high correlation to the beaver values, suggest a predominantly herbivorous diet for this

species. Further, the $\delta^{13}\text{C}$ values indicate terrestrial food sources. Isotopic signals from the two bear samples also indicate a surprisingly herbivorous diet, with $\delta^{15}\text{N}$ values of 3.8‰ and 3.9‰. $\delta^{13}\text{C}$ values for the same samples are higher than values from the pigs and beavers, -20.2‰ and -20.0‰. The two samples, both originating from phalanges, might represent the same individual, a possibility that is further implied by the similar isotopic signatures.

The fish-eating white winged scoter displays very varied isotopic values. Two of the samples have similar $\delta^{15}\text{N}$ values of 11.1‰ and 11.6‰, whereas the value for the third sample is 8.5‰, a difference of one trophic level. $\delta^{13}\text{C}$ values are even more dispersed, where the sample with the highest $\delta^{15}\text{N}$ value has a clearly terrestrial $\delta^{13}\text{C}$ value of -21.1‰, in contrast to the two other, more marine values of -16.1‰ and -17.1‰. Modern white winged scoters in the region breed along the Baltic coast as well as in terrestrial milieus, mainly the mountain lakes and coniferous forests of Northern Scandinavia (Lundevall & Bergström 2005:62). Differences in breeding environments might explain the variations in $\delta^{13}\text{C}$ values between the individuals.

The fish samples, representing herring and pike, have $\delta^{15}\text{N}$ values between 9.2‰ and 11.7‰, pike displaying the highest values. $\delta^{13}\text{C}$ values were more varied, for herring ranging between -15.5‰ and -13.8‰. The two samples of pike have more marine values, -12.3‰ and -12.2‰. Pikes live in freshwater milieus as well as in brackish littoral environments, such as the shallow water close to the Baltic coast (Curry-Lindahl 1985:261pp). Herring, on the other hand, is a pelagic species, its natural habitat is the open sea (Curry-Lindahl 1985:346pp). Studies have shown that species living in littoral environments are enriched in $\delta^{13}\text{C}$ compared to pelagic species (France 1995), and this can explain the difference in $\delta^{13}\text{C}$ values between pike and herring.

Only three of the six seal specimens fulfill the collagen quality criteria, one harp seal and two ringed seals. The values of the harp seal, -16.4‰ for $\delta^{13}\text{C}$ and 12.4‰ for $\delta^{15}\text{N}$, are very similar to those of one of the ringed seals, -16.5‰ and 12.3‰ for $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ respectively. The second ringed seal deviates somewhat, with a lower $\delta^{13}\text{C}$ value of -17.7‰ and a slightly higher $\delta^{15}\text{N}$ value of 13.1‰. The seals thus have lower $\delta^{13}\text{C}$ values than the fish, which can be explained by the differences in $\delta^{13}\text{C}$ values between pelagic and littoral consumers.

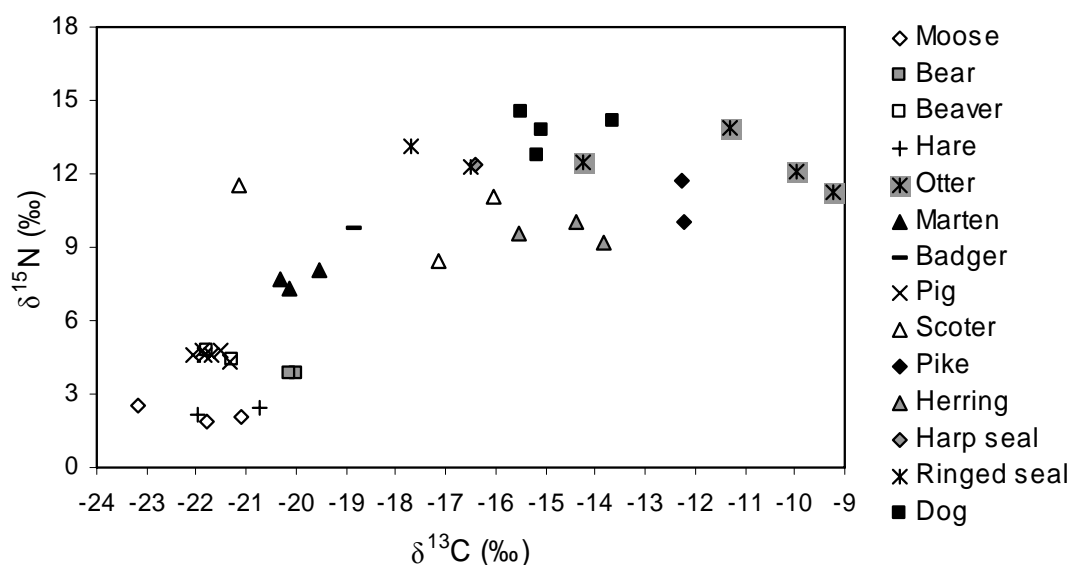


Fig. 6. Plot of isotopic $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values for the Korsnäs faunal samples.

KOR 30 was initially sampled as a badger, based on the size of the pelvis. Even though badgers are omnivores with highly varied food sources (Curry-Lindahl 1985:312pp), the extremely high $\delta^{13}\text{C}$ value (-9.2‰) caused the origin of the sample to be questioned. An additional osteological analysis resulted in a re-evaluation of the bone, which proved to belong to a remarkably large specimen of otter. The second badger displays values corresponding to a semi-terrestrial carnivore (-18.9‰ and 9.7‰ for $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ respectively). The otters, including KOR 30, are found about one trophic level up from the fish samples, with $\delta^{15}\text{N}$ values between 11.3 ‰ and 13.9‰. $\delta^{13}\text{C}$ values are dispersed, ranging between -14.2‰ and -9.2‰. The values indicate mainly marine food sources, where the individuals with the highest $\delta^{13}\text{C}$ value seems to have been eating exclusively littoral fish.

Three of the four dogs have $\delta^{13}\text{C}$ values between -15.1‰ and -15.5‰, one sample deviating from the rest with a value of -13.7‰. $\delta^{15}\text{N}$ values range from 12.8‰ to 14.5‰. The isotope data indicates that the dogs have been fed with seal and fish.

6.1.2 Human samples

Table 7. Carbon and nitrogen isotopic data for the human samples from Korsnäs. Marked samples are excluded since they fall outside quality ranges.

Ind. no. / Age	Context	Element	lab#	Bone/tooth (mg)	Collagen (mg)	Collagen (%)	$\delta^{13}\text{C}$ (‰)	$\delta^{15}\text{N}$ (‰)	% C	% N	C/N
ind. 1 adult		Humerus sin	KOR 40	93.90	1.33	1.4	-16.0	15.5	39.0	14.1	3.2
ind. 2 adult		Humerus dx	KOR 41	85.84	0.31	0.4	-	-	-	-	-
ind. 3 adult		Humerus dx	KOR 42	79.22	0.31	0.4	-	-	-	-	-
ind. 4 adult		Humerus dx	KOR 43	72.34	0.26	0.4	-	-	-	-	-
ind. 5 child		Humerus dx	KOR 44	67.35	2.85	4.2	-15.1	15.5	41.2	15.2	3.2
ind. 6 adult		Mandibula	KOR 45	98.91	0.36	0.4	-	-	-	-	-
ind. 6 adult		M₁ sin	KOR 46	63.09	0.37	0.6	-	-	-	-	-
ind. 7 adult		Mandibula	KOR 47	71.12	1.60	2.2	-16.2	15.8	40.0	14.5	3.2
ind. 7 adult		M₁ sin	KOR 48	57.01	0.25	0.4	-	-	-	-	-
ind. 7 adult		M ₂ sin.	KOR 49	58.72	0.80	1.4	-15.2	15.6	38.3	13.6	3.3
ind. 8 adult		Femur sin	KOR 50	90.62	5.51	6.1	-14.8	15.7	43.2	16.0	3.2
ind. 9 adult		Femur sin	KOR 51	101.73	0.88	0.9	-16.0	15.6	37.7	13.4	3.3
ind. 10 adult		Femur sin	KOR 52	87.08	1.17	1.3	-15.5	15.4	39.8	14.4	3.2
ind. 11 juv. / adult		Femur dx	KOR 53	108.21	1.27	1.2	-15.6	15.1	40.5	14.3	3.3
ind. 12 adult	Grave 3	M₂ sin	KOR 63	73.99	0.18	0.2	-	-	-	-	-
ind. 12 adult	Grave 3	M₃ sin	KOR 64	72.71	0.33	0.5	-	-	-	-	-
ind. 12 adult	Grave 3	M₁ sin	KOR 65	59.48	0.16	0.3	-	-	-	-	-
ind. 12 adult	Grave 3	Mandibula	KOR 66	70.26	0.24	0.3	-	-	-	-	-
ind. 13 adult	Grave 2	M ₂ sin	KOR 67	63.04	2.45	3.9	-13.1	15.5	39.7	14.9	3.1
ind. 13 adult	Grave 2	M1 sin	KOR 68	55.47	1.41	2.5	-13.7	15.4	40.2	14.9	3.1
ind. 13 adult	Grave 2	Mandibula	KOR 69	76.63	1.82	2.4	-13.8	15.7	41.2	15.3	3.1
ind. 14 child	Grave 1	Mandibula	KOR 70	72.25	2.34	3.2	-15.2	16.2	41.7	15.4	3.1
ind. 14 child	Grave 1	M ₁ dx	KOR 71	63.15	1.12	1.8	-15.2	15.6	40.4	14.7	3.2
ind. 14 child	Grave 1	dm ₂ dx	KOR 72	40.37	0.70	1.7	-16.1	15.9	38.1	13.0	3.4
ind. 14 child	Grave 1	dm ₁ dx	KOR 73	38.17	0.63	1.7	-15.4	16.6	32.5	12.1	3.1
ind. 14 child	Grave 1	dc	KOR 74	26.16	0.34	1.3	-16.5	15.8	36.0	12.0	3.5

The results of the stable isotope analysis on the human samples are presented in table 7 and fig. 7-9. Sixteen human samples were analysed through mass spectrometry, all of which fulfilled the quality criteria of C/N, % C and % N. Isotope values range between -16.5‰ and -13.1‰ for $\delta^{13}\text{C}$, and from 15.1‰ to 16.6‰ for $\delta^{15}\text{N}$. Mean and standard deviation of all human samples together is -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. $\delta^{15}\text{N}$ values are all about 3‰ higher than $\delta^{15}\text{N}$ values for the seals. $\delta^{13}\text{C}$ values are more dispersed, and the main part are more than 1‰ higher than $\delta^{13}\text{C}$ values for the seals. The highest $\delta^{15}\text{N}$ values originate from the child in grave 1, individual 14, whereas the juvenile/adult femur from individual 11 has the lowest value. Individual 13 (grave 2) has the highest and most deviating $\delta^{13}\text{C}$ values, indicating that these samples do not originate from the same individual as

any of the other samples. The lowest $\delta^{13}\text{C}$ values belong to individuals 1, 7 and 9. These three samples, representing a humerus, a femur and a mandible, all adult, display very similar isotopic signatures, and they might originate from the same individual. The no-context samples have total ranges of -16.2‰ to -14.8‰ for $\delta^{13}\text{C}$, and 15.1‰ to 15.8‰ for $\delta^{15}\text{N}$. Mean and standard deviation for the same individuals is -15.6 ± 0.5 for $\delta^{13}\text{C}$ and 15.5 ± 0.2 for $\delta^{15}\text{N}$. The standard deviation is thus lower for the no-context individuals than for all individuals together.

Both bone and teeth were analysed from individuals 7 and 13 and (fig. 8). For individual 7, only the mandible and the second molar yielded sufficient amounts of collagen, whereas the first molar was excluded from analysis. Results show a decrease in the $\delta^{13}\text{C}$ value between age ~ 7.5 years and adulthood of 1‰ (from -15.2‰ to -16.2‰). The $\delta^{15}\text{N}$ value increased 0.2‰ during the same period (from 15.6‰ to 15.8‰). From individual 13, both the first and second molar were analysed, together with the mandible. Between the ages ~ 3 and ~ 7.5 , 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‰). The mandible shows 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‰. The results do not indicate any major changes in diet for either of the two individuals.

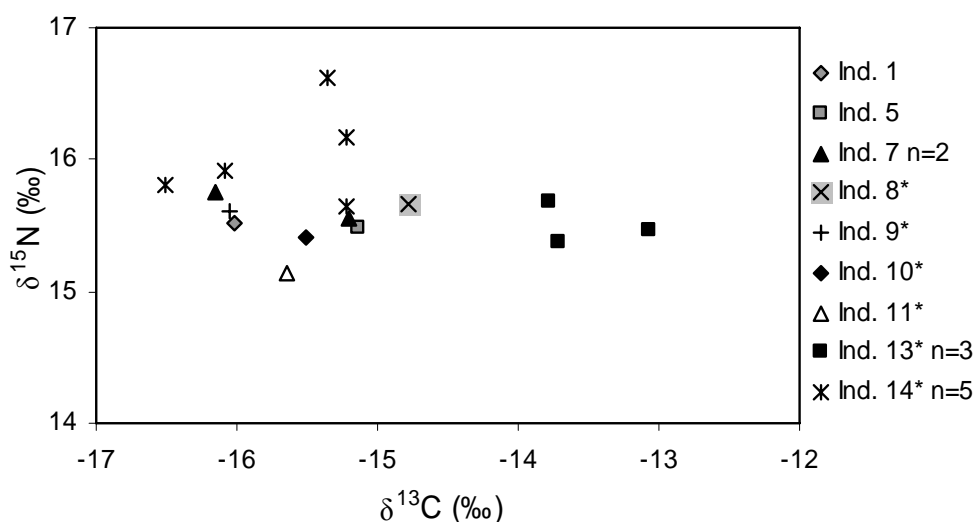


Fig. 7. Plot of isotopic $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values for the Korsnäs human samples. Individuals marked* are radiocarbon dated. n=number of analysed samples.

Teeth from individual 14 were analysed in an attempt to reconstruct the child's breastfeeding and subsequent weaning pattern (fig. 9). During breastfeeding, the child displays an increased $\delta^{15}\text{N}$ value, whereas the weaning process is signified by a decrease in $\delta^{15}\text{N}$. Since formation of deciduous teeth is initialized in the womb, the teeth display an average of $\delta^{15}\text{N}$ values from before and after birth. Elevated values will therefore not be as high as one trophic level (Lidén *et al.* ms). dm_1 , representing an age of ~ 5.5 months, displays an elevated $\delta^{15}\text{N}$ value of 16.6‰. At the age of ~ 9 - and ~ 10 months, the $\delta^{15}\text{N}$ value has decreased to 15.8‰ and 15.9‰ respectively. A similar value, 15.6‰ is given for the first permanent molar, representing ~ 3 years of age. The mandible, probably representing the last year of life, i.e. about 4 years of age, have a somewhat higher value of 16.2‰. The results indicate that the weaning process was initiated when the child was about 5-6 months old. The process appears to have ended somewhere between 9 and 36 months. The $\delta^{13}\text{C}$ values for this individual show a decrease from -15.4‰ to -16.1‰ between ~ 5.5 and ~ 10 months. At an age of ~ 3 years the value has increased to -15.2‰, and the same value is represented in the mandible sample.

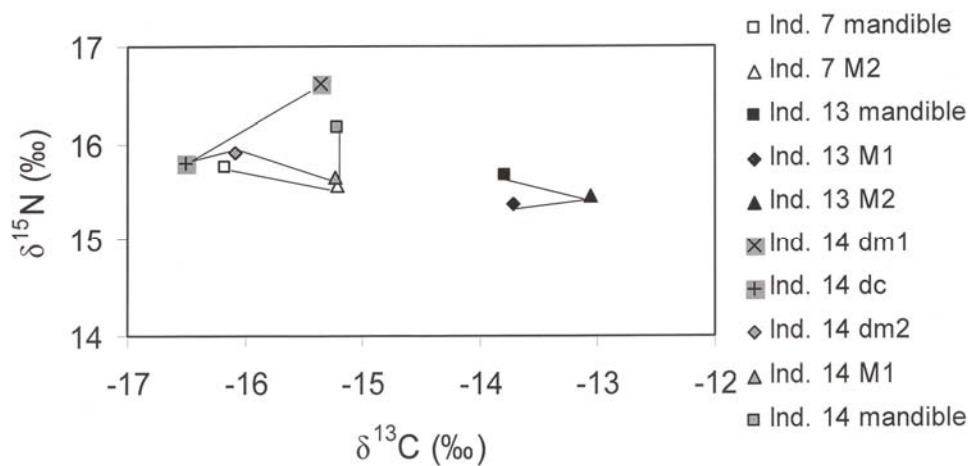


Fig. 8. Intra-individual changes in $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values studied through bone and tooth samples from individuals 7, 13 and 14 from Korsnäs.

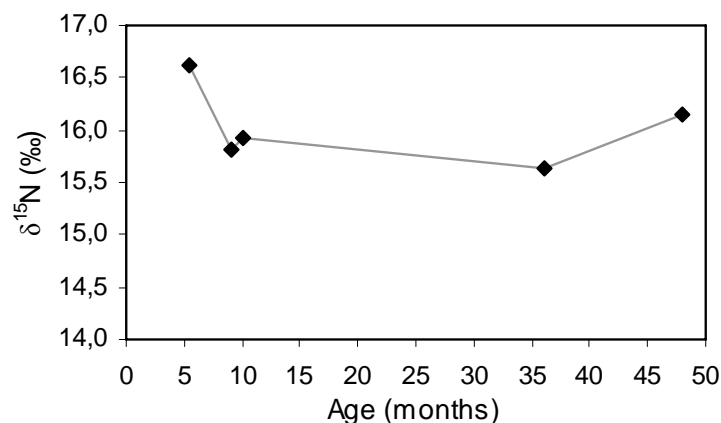


Fig. 9. Ind. 14 from Korsnäs. $\delta^{15}\text{N}$ values plotted against crown formation age of dm_1 , dc , dm_2 , M_1 , and age estimated to be represented by the mandible sample.

6.2 Radiocarbon dating

The radiocarbon dates ranged between 4540 ± 45 and 4145 ± 40 BP (table 8). The human samples together with the dog, all with marine $\delta^{13}\text{C}$ values, yielded dates between 4540 ± 45 and 4275 ± 45 BP, whereas the animals with terrestrial diets had younger radiocarbon dates, ranging between 4365 ± 40 and 4145 ± 40 BP. The BP dates were calibrated using OxCal v. 3.10. Calibrated dates for the wild animals ranged between 3080-2700 BC (1σ), largely corresponding to the second half of MN A. The human and dog samples yielded older calibrated dates between 3340-2880 BC (1σ)(fig.10). These samples are likely to exhibit apparent ages older than their actual ones, due to the reservoir effect. In order to estimate the extent of this effect, radiocarbon dates from samples representing both marine and terrestrial $\delta^{13}\text{C}$ values found in a closed context are required. Since the Korsnäs material does not offer such possibilities, the reservoir correction of 70 ± 40 years suggested for Middle Neolithic bones on Gotland (Eriksson 2004) is applied to the mentioned Korsnäs samples as well. The reliability of applying this estimation to Korsnäs is

Table 8. Results from the radiocarbon dating at Ångströmlaboratoriet.

Lab no.	Sample	$\delta^{13}\text{C}$ (‰)	^{14}C BP
Ua-32323	Moose	-21.8	4365 ± 40
Ua-32325	Bear	-20.0	4145 ± 40
Ua-32324	Pig	-21.3	4275 ± 40
Ua-32326	Dog	-13.7	4380 ± 45
Ua-32327	Ind. 8	-14.8	4470 ± 45
Ua-32328	Ind. 9	-16.0	4320 ± 45
Ua-32329	Ind.10	-15.5	4460 ± 45
Ua-32330	Ind. 11	-15.7	4540 ± 45
Ua-32331	Ind. 13	-13.8	4520 ± 45
Ua-32332	Ind. 14	-15.2	4275 ± 45

uncertain, but unfortunately no contemporary data from the Eastern Middle Sweden mainland is available. The reservoir effect will be further discussed below. After applying a reservoir correction of 70 ± 40 years, the dates for the dog and human samples fell within the interval 3170-2800 BC (1σ), correlating to the middle of MN A (fig. 11).

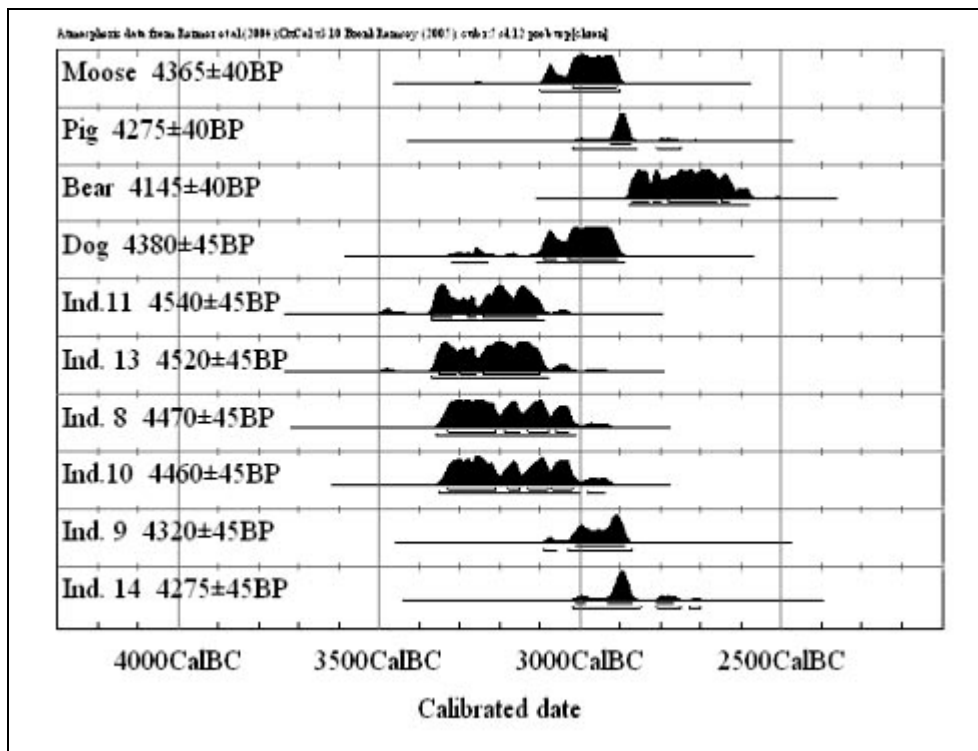


Fig. 10. Radiocarbon dates, calibrated with OxCal v. 3.10.

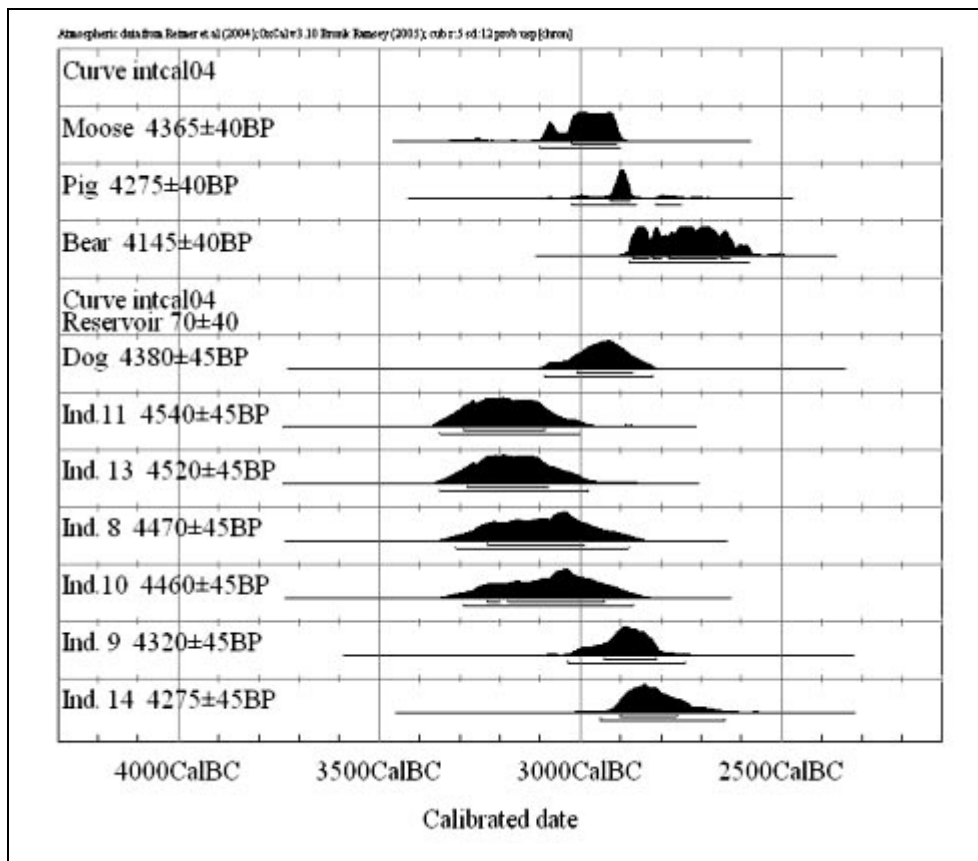


Fig. 11. Radiocarbon dates with a reservoir correction of 70 ± 40 years applied to the human samples together with the dog sample.

7. Discussion

7.1 Radiocarbon dates

Due to the uncertainty concerning the extent of the supposed reservoir effect it is problematic to draw any conclusions about the ages of the samples with marine $\delta^{13}\text{C}$ values. With this follows that any assessments of the length of the apparent continuity of the site must also be uncertain. It is unlikely that the dates from the wild animals are contemporary with each other, agreement between the samples is 7.3%, based on a calculation of combined probabilities in OxCal v.3.10. The correlation within the samples from dog and humans shows an even lower level of agreement of 2.3%. When calculating the total range for all wild animal dates, all samples with 68.2% probability fall within a range of up to 380 years, and with 95.4% probability within up to 470 years (fig. 12). The same calculation for the dog and human samples give ranges of up to 460 and 490 years respectively (fig. 13). This implies that, regardless of the extent of the reservoir effect, the Korsnäs site was habited or visited more or less continuously for several hundred years during the Middle Neolithic.

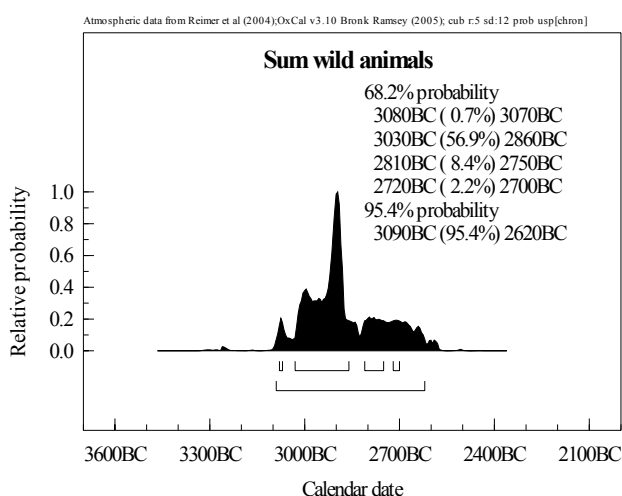


Fig. 12. Probability distribution for wild animals.

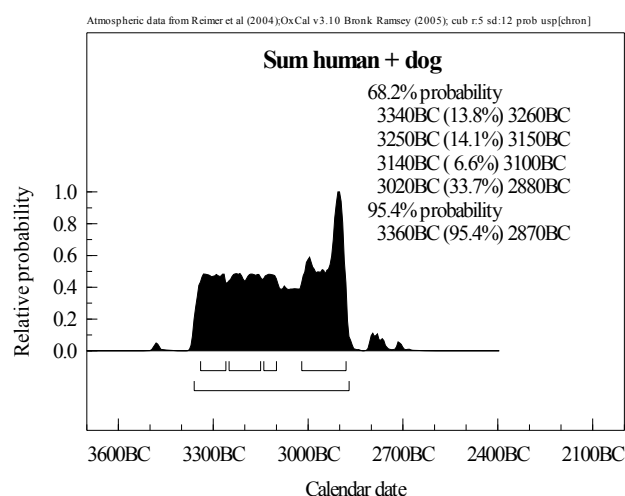


Fig. 13. Probability distribution for human + dog

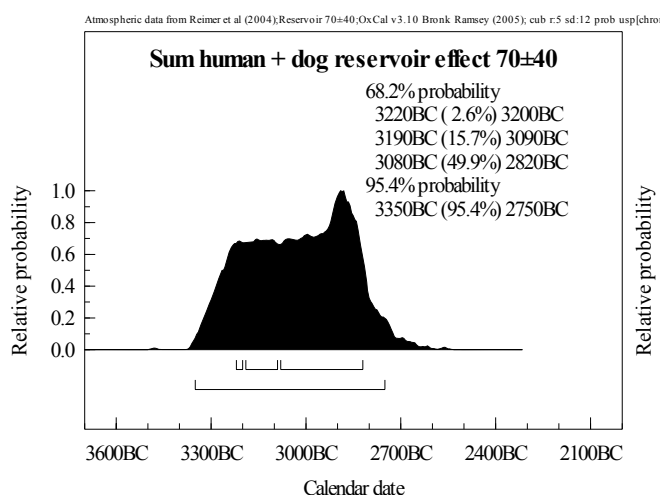


Fig. 14. Probability distribution for human + dog with a reservoir effect correction of 70±40 years.

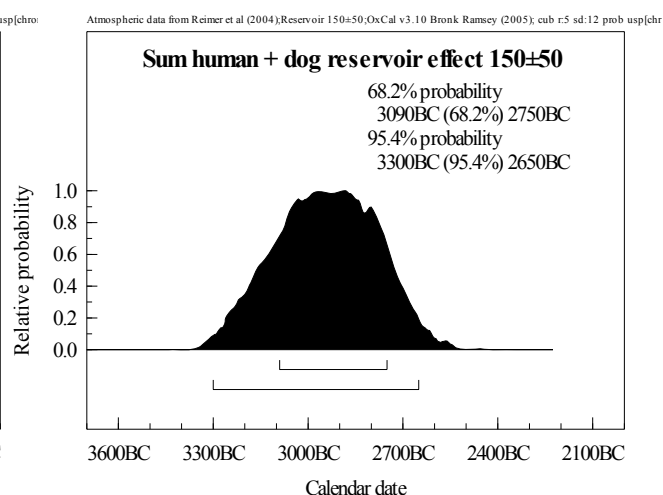


Fig. 15. Probability distribution for human + dog with a reservoir effect correction of 150±50 years.

With an estimated reservoir correction of 70 ± 40 years, the dog and human samples still yield dates that seem to be older than dates for the wild animals (fig. 14). If applying a hypothetical reservoir age offset of 150 ± 50 years, based on comparisons between the probability ranges of the wild animals and the human and dog samples, a better match is achieved (fig. 15). The calculated probability range for the dog and human samples of 3090-2750 BC (1σ) then correlates well with the same calculation for the wild animals, 3080-2700 BC (1σ). It should be noted that the correlation for 2σ is lower (3300-2560 BC and 3090-2620 BC respectively). In the absence of bones with varied $\delta^{13}\text{C}$ values from closed contexts among the sampled material from Korsnäs there is no way of testing this hypothetical correction factor here, and using the estimate of a reservoir age offset of 70 ± 40 years suggested for the Middle Neolithic on Gotland is therefore considered to be a preferable alternative for the time being. More knowledge about the local and temporal variations in the extent of the reservoir effect in the Baltic is certainly desirable.

Two of the three radiocarbon dates from 1978 correlate to the wild animal samples. $\delta^{13}\text{C}$ values for these pooled samples are consistent with a terrestrial diet, whereas the third sample, with an earlier date, have a $\delta^{13}\text{C}$ value indicating a total or partial intake of marine protein. The date of this sample correlates to the earliest human dates. An apparent age due to the reservoir effect is probable for this sample as well.

A reservoir correction of 70 ± 40 or 150 ± 50 both place the Korsnäs bones, with a high probability, within Middle Neolithic A, although there is a possibility that the child in grave 1 (ind. 14) and the bear might be dated to the initial phase of MN B (figs. 12, 13 and 15). The fact that the dates seem to correspond to MN A is important to note, considering that potsherds from the BAC have been found at Korsnäs. Since BAC artefacts appear in the region during MN B, it is unlikely that the dated bones are contemporary with the presence of BAC pottery at the site. The bone material seems to originate from PWC groups exclusively. The intriguing question of how the BAC representation on the site can be understood thus goes beyond the focus of this study.

7.2 Human diet

The method of establishing $\delta^{13}\text{C}$ end values from which the human diet can be approximated presents obvious problems when applied to the Korsnäs data. A terrestrial end value, (the estimated $\delta^{13}\text{C}$ value of an individual feeding off exclusively terrestrial protein) can be estimated to -21.8‰ , based on the mean value of the terrestrial herbivores moose and hare, and requires no further discussion. The marine samples, on the other hand, are highly varied, and depending on which samples are included in the calculation, the potential marine end values differ significantly, resulting in varying percentages of estimated marine protein input in the human diet (table 9). Further, estimates based on end values only regard $\delta^{13}\text{C}$, and do not take into consideration $\delta^{15}\text{N}$, nor the $\delta^{13}\text{C}$ increase of 1‰ per trophic level. In the case of Korsnäs, where several potential protein sources exist, within both the terrestrial and the marine $\delta^{13}\text{C}$ sphere, it is not preferable to base a reconstruction of the diet only on estimated end values. Instead, a graphic model is employed, showing the expectancy ranges of both $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values for different potential diets. Through adding values consistent with one step up the food chain, i.e. 3‰ for $\delta^{15}\text{N}$ and 1‰ for $\delta^{13}\text{C}$, to the isotopic values of a certain potential food source, expectancy values for individuals feeding off exclusively this particular species, or group of species, can be estimated. This approach has previously been employed by Eriksson (2004) in stable

Table 9. Estimate of marine protein input in human diet based on different calculations of marine end values. Estimated terrestrial end value, based on the mean value of the terrestrial herbivores moose and hare = -21.8‰ . Mean $\delta^{13}\text{C}$ value for humans = $-15.2\pm1.0\text{‰}$.

Selection	End value (‰)	Estimated marine input in diet (%)
Fish	-13.6‰	80 ± 12
Seal/fish	-14.8‰	94 ± 14
Seal/pelagic fish	-15.7‰	100
Seal	-16.9‰	100

isotope analyses on PWC material from Västernbiers, Gotland.

Expectancy values for four potential groups of food sources, moose/hare, pig, seal and fish, were plotted against isotopic data from humans, dogs and otters (fig. 16). Otters were included since they represent fish eaters. The diet of dogs compared to humans is discussed in another section of this chapter. It is evident from fig. 16 that the predominant protein component in the diet of all sampled human individuals originates from marine animals. No human sample yields a lower $\delta^{13}\text{C}$ value than the expectancy values for the seal consumption. The $\delta^{13}\text{C}$ values could be the result of a diet consisting of fish together with terrestrial animals, but such a diet would probably have yielded lower $\delta^{15}\text{N}$ values than the ones displayed here. Rather, the human $\delta^{15}\text{N}$ values are consistent with consumption of seal, indicating that any possible terrestrial protein input in the diet is too small to leave any trace in the dietary signal.

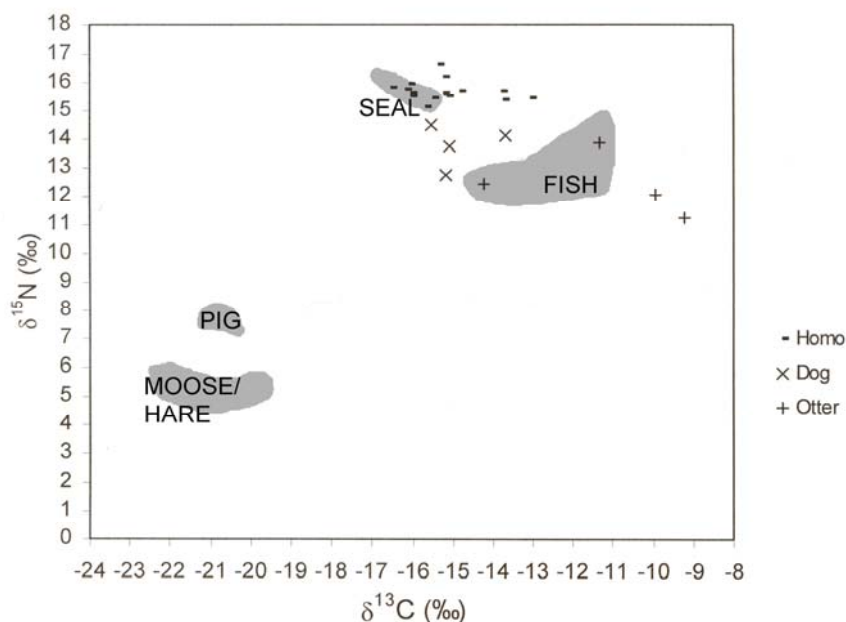


Fig. 16. Expectancy fields for individuals feeding off different protein sources plotted against carbon and nitrogen isotopic values for human, dog and otter samples.

Interpreting the human diet as predominantly marine based on the faunal expectancy values poses no significant uncertainties. Identifying the proportions of different marine species in the dietary signals is more problematic. Most of the human samples plot within or close to the expectancy range for seal eaters, although the $\delta^{13}\text{C}$ values for some of these samples are slightly too high to fit into this field. The relatively high $\delta^{13}\text{C}$ values for the three samples from the adult individual in grave 2 (ind. 13) deviate from the other humans, possibly indicating a significant input of fish in the diet. $\delta^{13}\text{C}$ values for individual 13 correspond to the expectancy values for herring, but the $\delta^{15}\text{N}$ values rather indicate that the humans are situated one trophic level above potential consumers of herring. Further, none of the human samples have a diet similar to that of the otters.

It is unfortunate that only three of the seal samples from Korsnäs fulfilled the quality criteria. Additional data on the seals' dietary signals is needed in order to draw conclusions as to whether or not the Korsnäs people were predominantly seal eaters. In the absence of sufficient data from Korsnäs, isotopic signals of seal bones recovered from the PWC sites Västernbiers and Ire on Gotland (Eriksson 2004) are applied in an attempt to estimate the proportions of seal in the human diet (fig. 17). The adequacy of including bones from another area in the analysis might be questioned, since $\delta^{13}\text{C}$ values of the Baltic have fluctuated over time and space. The problems involved might be less for the harp seal, which is the dominant seal species on the Korsnäs site, than for the ringed seal, since the harp seal is migratory while the ringed seal is more stationary (Curry-Lindahl 1998:334pp). The former is therefore more likely to display an "average Baltic"

isotopic signature, whereas $\delta^{13}\text{C}$ values of the latter rather mirror local conditions. Further, radiocarbon dates place the Västerbjers site in MN B (Eriksson 2004), whereas the Korsnäs people are likely to belong to MN A. It is possible that the temporal fluctuations in salinity in the Baltic have caused $\delta^{13}\text{C}$ values to vary between these two periods. Nevertheless, this application can be considered the most fruitful way of estimating possible isotopic values for seal consumers at Korsnäs, until additional data on isotopic signatures for seals in the vicinity of Södertörn, and dated to MN A, is available. The expectancy field of the seals from Gotland and Korsnäs combined correlates to the dietary signals of all human individuals except individual 13. This indicates that the analysed Korsnäs humans, with a possible exception of individual 13 (who might have included a significant intake of fish in the diet), were predominantly seal-hunters, and that the proportions of terrestrial animals in the diet were negligible.

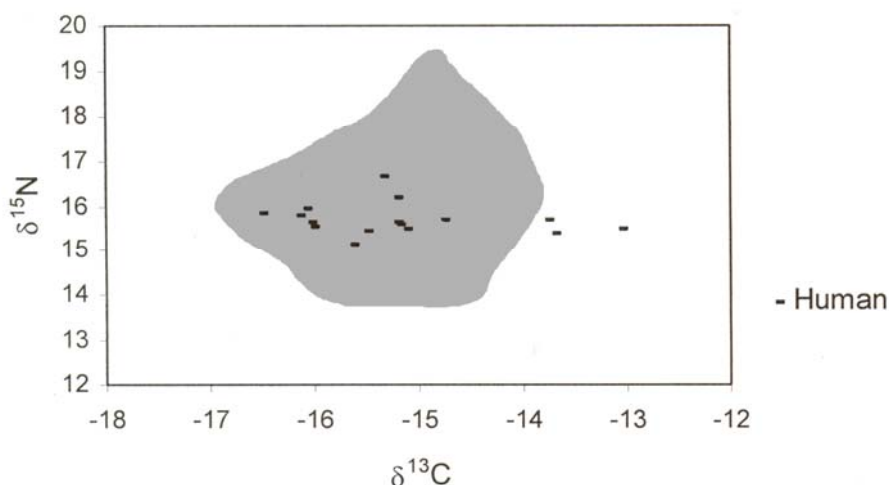


Fig. 17. Expectancy field for individuals feeding off seal from the Baltic plotted against isotopic data from the Korsnäs human samples. Isotopic values for seal are based on data from Västerbjers and Ire (Eriksson 2004) together with Korsnäs.

It is interesting to note that the individual who deviates from the rest regarding the isotopic signature, individual 13, is deviating in other ways as well. The mandible of this individual was accompanied with burial gifts in the grave, consisting of a dog cranium with a clay bead in one eye-socket, a curved chisel, marking an eastern influence, and significant amounts of fish bones, mainly herring. Can the special treatment of this individual, together with the diverging dietary pattern, indicate a special status in society? Or do the high $\delta^{13}\text{C}$ values together with the grave goods indicate that the individual is not originally from Korsnäs? From this perspective the eastern influence identified through the curved chisel is interesting. The occurrence of fish bones in the grave does not necessarily mirror any dietary patterns. Discrepancies between the symbolic world, as identified in the grave material, and everyday practice (in terms of diet) have previously been identified at Västerbjers, where animal remains in the grave goods are clearly dominated by pig bones and tusks, whereas the human diet is made up of seal (Eriksson 2004). It should be noted, that individual 13 was found in a structure identified as a *possible* grave. Only the mandible of the individual seems to have been deposited, and it is possible that the meanings associated with this “burial” differ from those of other graves on the site. Perhaps the mandible, together with the dog cranium and other artefacts, were deposited in a sacrificial context. From this perspective, and especially when taking into account the stable isotope data, one can ask whether individual 13 has ever lived on the Korsnäs site. Unfortunately, we cannot know if or how the Korsnäs people distinguished between graves and sacrificial deposits of human bones, and it is evident that human remains were treated in a variety of different ways. The presence of scattered human bones on PWC sites raises even more questions about conceptions and meanings concerning the treatment of the dead.

Analysis of the intra-individual dietary pattern for individual 7 shows a decrease in the $\delta^{13}\text{C}$ value between age ~ 7.5 and adulthood. Values for both M_2 and mandible seem to correspond to a diet of seal, although it cannot be ruled out that the higher $\delta^{13}\text{C}$ value for the molar is caused by an input of fish in the diet during the time when the tooth was formed. Individual 13 displays an increased $\delta^{13}\text{C}$ value in M_2 compared to M_1 and the mandible, indicating a possible increase of the input of fish in the diet sometime after the first years of life, and a possible decreased input of fish after the age of ~ 7.5 . These possible intra-individual changes are rather small scaled, and there is no evidence of any temporary inputs of terrestrial protein in any of the samples.

The analysis of the breastfeeding pattern of individual 14 can be compared with data from two PWC children from Ire and Västernbys, Gotland (Eriksson 2003). The studies show both uniting and differing features. Weaning was initiated at an age of ~ 6 months for all three individuals, but the lengths of this process vary. Values from the Ire child indicate that weaning was completed at 1.5 years, whereas the process continued until an age of 4 years for the child from Västernbys. Completed weaning for individual 14 from Korsnäs cannot be determined. There do not seem to have been any consistency within the PWC regarding the duration of weaning, but it is possible that the initiation of the process followed a specific social code.

Neither the radiocarbon dates nor the isotopic data indicate any features separating the stray find individuals from the grave individuals. Individual 14 has the youngest radiocarbon date, but the isotopic values correspond to the stray find individuals, provided that the elevated $\delta^{15}\text{N}$ values of the child are explained as the result of breastfeeding. Individual 13, on the other hand deviates regarding the dietary pattern, whereas the radiocarbon date corresponds to the stray find individuals. If individual 13, who clearly deviates from the other individuals, is excluded, the standard deviation for the remaining human samples is 0.5‰ for $\delta^{13}\text{C}$ and 0.4‰ for $\delta^{15}\text{N}$. According to Lovell *et al.* (1986:51), a population with a homogeneous diet has a standard deviation in $\delta^{13}\text{C}$ of $<0.3\text{‰}$. If applying this perspective, the diet of the Korsnäs people will be regarded as heterogeneous. However, due to the small size of the sampled population, the adequacy of such an estimate on the Korsnäs material must be questioned.

7.3 Wild boar or domestic pig?

The question of whether or not the Pitted Ware people kept domestic pigs has been subject to extensive debate. The main focus has been Gotland, where pigs are not indigenous and were introduced by human agency, probably at the beginning of the Neolithic (Lindqvist & Possnert 1997:64p). The fact that the species were brought to the island by humans has been used as an indicator of pig domestication by PWC people on Gotland (e.g. Jonsson 1986, Lindqvist & Possnert 1997:65). Österholm (1989:28) regards the presence of significant 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 pigs are interpreted by Österholm as being domesticated in the sense that they were provided with shelter close to human settlements and could feed on food waste. The Gotland domestication hypothesis has further been supported by e.g. Wallin & Martinsson-Wallin (1992:9) and Hedemark *et al.* (2000:16).

A presence of domestic pigs has also been suggested for the mainland PWC sites. Jonsson (1986) argues that since the large size of the mainland Neolithic pigs correlates to the Gotland specimens (which are regarded to be domestic, see above), they should be interpreted as being domesticated. Benecke (1993:241p) identifies a division of the Neolithic pigs into two morphologically different groups, where the smaller specimens are considered to be domestic. Further, age estimates on PWC pig remains indicating a high frequency of young specimens (up to 2 years) are regarded as further evidence of domestication. A standard way of separating wild pigs from domesticated ones is

through measurements of the length of the third molar (Welinder *et al.* 1998:82p, Magnell 2005:61), a method through which During (1986:124) identified pigs at an early stage of domestication in the Alvastra material.

The domestication hypothesis is contradicted by e.g. Ekman (1974:216), who interprets the pigs from Gotland and Alvastra (with one exception) as wild, based on third molar length measurements. Rowley-Conwy and Storå (1997:121pp) strongly criticize the suggested presence of domestic pigs on Gotland, arguing that metrical evidence is problematic and questionable, that importing of wild animals to islands is known in 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. Rowley-Conwy and Storå (1997:124p) 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. Lepiksaar (1974:148p) 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.

The problems with separating wild boar from domestic pigs are further stressed by e.g. Rowley-Conwy (1995) and Magnell (2005). Magnell (2005:61,93) questions the accuracy of identification of domestic pigs based on dental measurements, and stresses the need for a better understanding of osteological data characteristic of hunted wild boar, including age distribution, body part representation and osteometrics, in order to increase the analytical possibilities of distinguishing between wild and domestic pigs. These problems further imply the need for additional methods, where isotope analysis of diet can be a valuable source of information. Since domestic or semi-domestic pigs are likely to feed on waste products from human food preparation, and since agricultural activities seem to be absent from PWC sites, the diet of domestic pigs ought to include a significant proportion of marine protein, reflecting the major protein source for the humans. As far as the pigs from Korsnäs are concerned, no such influence can be identified in the isotopic signature from any of the pigs. Here, the animals seem to have a homogeneous terrestrial, mainly herbivorous diet that in no way correlates to the human marine carnivorous diet. No differences in the dietary signals, for example between pigs of different sizes, can be distinguished. This implies that all analysed pigs were feeding off vegetable food sources, and thus were wild rather than domesticated. Previous stable isotope studies on pigs from Västerbjers, Gotland by Eriksson (2004) yielded similar results, and the animals were interpreted as wild boar or feral pigs. The isotopic data together with a lack of evidence supporting a domestication of pig within the PWC imply that the PWC groups were (occasional) wild boar hunters rather than pig breeders. The results from Korsnäs and Västerbjers might also contradict Lepiksaar's view of the PWC pigs as wild boar feeding off human waste products during cold winters, since no pig show any evidence of such a component in their diet.

7.4 Dogs

The dog seems to make up the only representation of domestic species on the Korsnäs site. Its symbolic role in Korsnäs is evident in the presence of dog tooth beads (Sjöling 2000:18) and through the dog cranium found in grave 2. Tooth beads from dogs are also known from the PWC site Äs, Västmanland, and the PWC/FBC site of Alvastra, Östergötland (Sjöling 2000:34pp). The multiple roles of dogs, both sacred and secular, together with the varied perceptions and attitudes towards the species in prehistory, has been discussed by Olsen (2000). Jennbert (2003:149p) suggests that in prehistory, certain animals, such as dogs, were transformed into cultural categories, and thus participated in the collective. It has been suggested that the diet of dogs might be used as a proxy for human diet in the absence of human bone material (e.g. Schulting & Richards 2002a), a

view that has been criticized and contradicted by e.g. Eriksson (2003:21) and Eriksson & Zagorska (2003). The data from Korsnäs shows that the isotopic values for humans differ from values for the dogs (fig. 16). To approximate human diet from the isotopic data of the Korsnäs dogs would therefore yield erroneous results.

7.5 Faunal assemblage and diet

The faunal assemblage quantified by Aaris-Sørensen (1978) only includes material from the 1970 excavation, but since the bones from the other surveying contexts still remain to be analysed, they must be left out of this report. This means that the representativeness of the identified bones might be questioned, especially when taking into account that they represent only 136 m² of an approximately 95,000 m² activity area. Any application of this material to the site as a whole must be hypothetical. Nevertheless, it is evident that a few species dominate among the animal bones, and that there are no accumulations of a certain species that can account for this dominance. This implies that the animal bones deposited at the Korsnäs site mainly represent seal and pig. The high weight percentage of moose can be explained by the heavy weight of the moose bones rather than by frequent depositions. During the excavation, a coarse-meshed sieve was used (Olsson *et al.* 1994:13), meaning that the proportion of fish might not be representative since very fine bones would have passed through the sieve.

Based on the relative proportions of faunal species on the site, Aaris-Sørensen (1978:16p) suggests an economy where wild boar and seal, together with significant amounts of fish, made up the main food sources. The method of reconstructing subsistence patterns from the faunal assemblage has been applied to several other PWC sites as well (e.g. Ekman 1974, Ridderstråhle 1979, Ericson & Forendal 1980, Hårding 1996). 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. The use of wild animals as sources of fur, bone, antler and other production raw material cannot alone explain this discrepancy. For example, there are more identified artefacts of seal bone than of pig bone/tusks on the Korsnäs site (Sjöling 2000). In order to understand the meanings of the animal bones, it is necessary to look beyond economic aspects.

The high percentage of pig bones on Korsnäs, most probably originating from wild boar, implies a symbolic significance of this species. It is evident that pig did not constitute a part of the everyday diet, but it is possible that pork was consumed on certain occasions. Pig bones might have been intentionally deposited at the site to a greater extent than the seal bones, which would explain why these two species are almost equally represented. On Västerbjers, where pig remains clearly dominate over seal bones, the human diet, as in Korsnäs, was based on seal (Eriksson 2004). Could hunting and feasting/sacrificing of wild boar be a ritual aspect of the Pitted Ware Culture? Pig mandibles, tusks and tooth beads are common features in PWC graves on Gotland (Ekman 1974:214, Janzon 1974:46-108), and even though grave goods are very rare on Korsnäs and do not include remains of pig, a similar symbolic importance of the animal might be implied in the presence of beads and pendants of boar tusks and teeth (Sjöling 2000). The tooth beads further indicate a symbolic importance of several other species, and include teeth from seal, moose, dog, bear, marten and lynx (Sjöling 2000:19).

7.6 Comparative analysis

In order to understand Korsnäs in its PWC context, it is necessary to discuss the faunal and dietary record from other PWC sites in the eastern region. Further, the results of the stable isotope analysis shed light on the need to re-evaluate some of the prevailing conceptions about PWC economy and ideology. For these reasons, a comparison of the faunal assemblages and (where present) dietary evidence between a number of PWC sites in the eastern region is presented (table 10). The sites represent different environmental conditions, and the selection is based on occurrence of available osteological faunal analyses and stable isotope data. The study includes the following sites (with

references to the faunal data. For a view of the sites' geographic locations, see fig. 1):

- Överåda, Trosa-Vagnhärad parish, Södermanland (Welinder 1971)
- Häggsta III-V, Botkyrka parish, Södermanland (Hårding 1996, Olsson, E. 1996a)
- Åloppe, Nysätra parish, Uppland (Olson 1994)
- Äs, Romfartuna parish, Västmanland (Lepiksaar 1974)
- Åby, Kvillinge parish, Östergötland (Kjellström 1996)
- Alvastra, Västra Tollstad parish, Östergötland (During 1986)
- Jettböle, Jomala parish, Åland, Finland (Lidén *et al.* 1995)
- Köpingsvik, Köping parish, Öland (Ridderstråhle 1979, Ericson & Forendal 1980)
- Västerbjers, Gothem parish, Gotland (Ekman 1974)
- Ire, Hangvar parish, Gotland (Ekman 1974)
- Ajvide, Eksta parish, Gotland (Lindqvist & Possnert 1997)

Due to the before-mentioned quantification problems, fish bones are not included in the comparison. Further, birds are excluded since their importance in human diet is considered negligible. Since seal and pig generally constitute the most common mammal species in PWC contexts, the seal to pig ratio for the different sites is calculated. Occurrences of domesticated animals (except dogs) are included, as is other mammal species representing 5% or more of the total mammal bones. Unfortunately, there is no consensus in the osteological reports regarding which parameters to quantify. Therefore, the number of identified specimens (NISP) is used as the basis for the calculations where possible, but in some cases other parameters must be used. This complicates comparisons between the sites, but since it is the overall picture that is of importance here, the data can still be regarded to be sufficient for the present purpose.

Table 10. Comparison of PWC sites in the eastern region. NISP = number of identified specimens, MNI = minimum number of individuals. "Diet" refers to stable isotope data. "Other" refers to wild mammals, except seal and pig, comprising 5% or more of the total amount of identified mammal bones on the site. % refers to percentage of the total amount of mammal bones.

Site	Environment	Seal:Pig ratio	Cattle, Sheep/Goat	Other	Diet
Korsnäs	Inner archipelagic	1.9:1 (NISP) 1:1.1 (MNI)			Seal
Överåda	Middle archipelagic	45:1 (find numbers)			
Häggsta	Inner archipelagic	1:1.8 (NISP)	Cattle 10% (NISP)		
Åloppe	Bay, inner archipelagic	2.4:1 (NISP)	Sheep/goat 0.2% (NISP)	Moose 5% (NISP)	
Äs	Deep inner archipelagic	1.5:1 (NISP)	Cattle 0.2% (NISP)	Moose 5% (NISP)	
Åby	Coastal bay	4.6:1 (NISP)	Cattle 6 teeth, possibly recent Sheep/goat <0.1% (NISP)		
Alvastra	Inland (FBC+PWC)	No seal. Pig 34% (NISP)	Cattle 45% (NISP) Sheep/goat 4% (NISP)		Terrestrial (Sælebakke & Welinder 1988)
Jettböle	Archipelagic	No pig. Seal 98% (NISP)	Cattle <1% (NISP)		Marine (Lidén <i>et al.</i> 1995)
Köpingsvik	Coastal	1.8:1 (MNI)	Cattle 6.4 weight% Sheep/goat 0.3 weight%		Seal (Eriksson pers. comm.)
Västerbjers	Coastal bay	1:6.7 (NISP)	Cattle 6% (NISP)		Seal (Eriksson 2004)
Ire	Coastal	9.1:1 (NISP)	Cattle 0.1% (NISP) Sheep/goat 0.7% (NISP)		Marine (Lidén 1996)
Ajvide	Coastal	1:1.2 (NISP)	Cattle <0.1% (NISP)		Mainly marine (Lidén 1996)

Domestic species are present on all but two sites. At Alvastra, nearly half of the mammal bones consist of cattle and sheep. This inland site, a pile dwelling in the middle of a peat bog, includes possibly contemporary artefacts belonging to both the FBC and the PWC (Browall 2003:55), and it can be questioned whether the Alvastra faunal assemblage is representative for an inland PWC site. Alvastra was included in this study in the absence of other inland PWC sites with available osteological and isotopic data. Radiocarbon dates on cattle and sheep bones from Västerbjers (Eriksson 2004) and four PWC sites on Åland, including Jettböle (Storå 2000) all belong to the Late Neolithic, Bronze Age or historic time. The six cattle teeth found at the Åby site are all unburned, and thereby differ from the rest of the faunal material, which consists almost exclusively of burned bone fragments. This causes Kjellström (1996) to suggest a possible recent date for the cattle teeth. There are no radiocarbon dates that place the domestic bones from any of the sites in the Early or Middle Neolithic. Since later intrusions are known from several locations, it is quite possible that this is the case for the rest of the sites as well. Some of the undated cattle bones were found in what are described as closed, definite PWC contexts (Lepiksaar 1974:146, Olsson, E. 1996a:68), but since there are no radiocarbon dates to support these interpretations, there is as of yet no irrefutable evidence of any PWC domestics (the problems involved with separating between wild and domestic pig are discussed above). Further, fragmentary occurrences of bones from domestic animals might be the result of contacts with FBC or BAC groups.

The proportions of seal to pig vary significantly between the sites. This variation cannot be explained solely in terms of location. Seal to pig ratios on Häggsta and Korsnäs, both located on Södertörn, are similar, whereas Överåda, also a Södertörn site, deviates markedly. Significant differences can also be identified between the Gotland sites. It is evident that the seal to pig ratio have no direct correlation with the dietary pattern, since all sites with stable isotope data, except Alvastra, indicate a predominantly marine diet, regardless of the amounts of pig bones present. The analysed individuals from Alvastra might not belong to the PWC. The vicinity to the coast is evident in the location of all sites, with the exception of Alvastra, and this is one of the most typical features of the PWC. The environmental conditions favoured a subsistence based on marine resources, although in the inner archipelago, several terrestrial protein sources are likely to have been available as well. On the inner archipelagic PWC site Korsnäs, these terrestrial resources were not included in the diet. Whether located on a Baltic island or in the archipelago of the mainland coast, the PWC people evidently chose to take their food from the sea. Conclusively, the human diet cannot with plausibility be estimated based on the faunal assemblage, and previous interpretations of the economy on several PWC sites must be re-evaluated.

7.7 Concluding remarks - Korsnäs and the PWC

A fundamental feature in this study is the perception that the differences in material culture during the Neolithic mirror more or less complex groups of people with varying ideologies, one of them being the Pitted Ware Culture. This view is in no way contradicted by the results of the dietary analysis of the Korsnäs people. On the contrary, regionally uniting features seem to be revealed. The PWC identity was an identity of seal hunting, regardless of the potential food sources available, the people chose to base their diet almost exclusively on what was offered from the sea. Apart from the seal, a symbolic significance also appears to have been assigned to the wild boar. Domestic ideals, prevalent within the contemporary ideologies of the Funnel Beaker Culture and the Battle Axe Culture, were not incorporated into the identity of the Pitted Ware People. Apparently, the Neolithisation process was not all-embracing, and the Pitted Ware Culture in Eastern Middle Sweden stands apart as a wild side of the Neolithic.

8. Summary

The Pitted Ware Culture site Korsnäs in Södermanland, Sweden presents high amounts of preserved organic material. This makes the site unique on the Eastern Middle Sweden mainland, where preservation conditions are generally poor. The faunal assemblage on the site is dominated by seal

and pig bones, and fish bones are suggested to have been frequent in the cultural layer, although not observed during the excavation. One of the aims of this study is to analyse the relationship between the faunal assemblage and the diet of the Korsnäs people. It is assumed that the diet is an important identity bearer, and therefore influenced by Pitted Ware Culture ideals. Previous dietary studies on material from Pitted Ware contexts on the Baltic islands indicate a marine diet, where the seal seems to be the predominant prey. Korsnäs is the first mainland Pitted Ware site in Eastern Middle Sweden to be subjected to dietary analysis, and a main question is whether this seal hunting identity can be traced in the bones of the Korsnäs people as well. The high frequency of pig bones also deserves special attention, since it has been debated whether or not the PWC people kept domestic pigs. Dietary analysis on pigs can shed light on this issue.

Faunal and human bone and tooth samples have been subjected to stable isotope analysis. The relative proportions of the stable isotopes ^{15}N to ^{14}N ($\delta^{15}\text{N}$) and ^{13}C to ^{12}C ($\delta^{13}\text{C}$) in collagen mirror an individual's main protein intake. $\delta^{13}\text{C}$ values can tell whether the diet was based on terrestrial or marine resources, whereas $\delta^{15}\text{N}$ is enriched for each step up the food chain, and therefore gives information about the trophic level of the individual. Collagen in bone has a turnover rate of 5-20 years, and stable isotope analysis on bone yields information on the average diet during several years prior to death. Collagen in teeth has no turnover rate, and studies on teeth show the diet of the time of tooth formation. Through studying both bone and tooth samples from the same individual, intra-individual changes can be observed. Further, analysis on deciduous teeth can be applied in studies of breastfeeding and weaning patterns, since $\delta^{15}\text{N}$ values are enriched in infants during nursing. Human samples originating from graves as well as scattered throughout the cultural layer were selected for analysis, together with faunal samples representing different steps in the marine and terrestrial food chains. Contemporary local faunal samples yield reference values that help interpret the human isotopic signals. Pigs were sampled in order to study the possibilities of domestication through dietary analysis.

Ten samples, both human and animal, have been radiocarbon dated. The dates largely correlate to Middle Neolithic A, which is important to note, since Battle Axe Culture potsherds have been recovered on the site. Artefacts assigned to this culture appear in the region during Middle Neolithic B, i.e., later than the dated bones from the Korsnäs site. There is therefore no evidence of any contemporaneity between PWC and possible BAC groups on the site.

The results of the stable isotope analysis show a predominantly marine protein intake for all sampled human individuals. The isotopic values indicate a diet based on predominantly seal, with the exception of one individual who, in addition to seal, might have had a significant intake of marine fish in the diet. Analyses on both bone and teeth from two individuals indicate no significant changes in diet from childhood to adulthood. Deciduous teeth were sampled from one child, and the results indicate that weaning was initiated at an age of 5-6 months. The diet of the pigs deviates significantly from the human diet, with terrestrial, herbivorous isotopic values. This implies that the pigs were in fact wild boar, since domestic pigs are likely to feed on waste products from human food production. The high proportion of pig bones on the site might indicate that wild boar was a symbolically important animal, which was sacrificed and/or ritually consumed on certain occasions.

The faunal assemblage and human diet of the Korsnäs site were compared with contemporary Pitted Ware sites in Eastern Middle Sweden and Åland. The results show that the proportions of seal and pig bones vary on the sites. Where present, however, stable isotope data, regardless of the faunal proportions, indicate a marine diet. Estimating diet on a Pitted Ware site from quantifications of the animal bones is therefore not a preferable method. The Pitted Ware Culture in Eastern Middle Sweden and Åland seems to be an identity based on seal-hunting, where wild boar was assigned a symbolic meaning, and where Neolithic ideals of domestication were not embraced.

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Key to Antiquarian Topographic Archive (ATA)

ATA dnr 4197/30: Ivar Schnell, report of settlement site at Korsnäs.

ATA dnr 3683/33: Stockholm Högskola, seminar excavation 1933.

ATA dnr 3347/64: Archaeological survey, Stockholms Högskola 1964, Grödinge Hembygdsförening, sieving of dump heaps 1971-72.

Personal comments

Eriksson, G., Archaeological research laboratory, April 2006

Storå, J., Osteoarchaeological research laboratory, March 2006

CD-uppsatser i laborativ arkeologi för läsåret 2005/2006:

KARIN ANDERSSON	Diet & Identitet. Analyser av kol- kväve- och svavelisotoper på indivier från det kristna senvikingatida gravfältet i Björned, Torsåkers socken, Ångermanland.
ANNA BÄCKHEDEN	Beslag eller buckla? En studie av platta järnfragment från hallhuset i Birkas Garnison.
ELIN FORNANDER	The Wild Side of the Neolithic. A study of Pitted Ware diet and ideology through analysis of stable carbon and nitrogen isotopes in skeletal material from Korsnäs, Grödinge parish, Södermanland.
MALTE FRIDÉN	Diet under mesolitikum utifrån analys av stabila isotoper i benmaterial.
HARALD JOHANSSON	”Båtnitar” – Analys och konservering av järnnitar från Birkas garnison.
FREDRIK LUNDSTRÖM	Det vikingatida bågskyttet i Birka – ett exempl på en framstående stridskonst med främmande inslag.
ELINA PALOMÄKI	Albys skärvor – Lipid och morfologisk analys av tidigneolitisk keramik från Öland.
ELLINOR SABEL	Arkeologisk landskapsanalys och prospektering av bebyggelse-lämningar och gravfält vid Alsike hage.
PIA SCHOULTZ	Genus på menyn. Analyser av stabila kol- och kväveisotoper på skelettmaterial från Bjärbygravfältet från äldre romersk järnålder i Kastlösa på Öland.
CHRISTINA SCHIERMAN	Bröd vid död i Kalvshälla. Analys av förhistoriskt organiskt grav- och boplatismaterial från Barkarby i Järfälla socken, Uppland.

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