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Mammalian stable isotope ecology in a Mesolithic lagoon at Skateholm

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Faunal remains from the settlement layers at the Late Mesolithic sites Skateholm I and II, Scania, Sweden, were subjected to stable carbon and nitrogen isotope analysis, and terrestrial and marine isotopic end-values for the site were established. The various stages that the Baltic Sea has passed through entail varying salinity, and although the correlation between salinity and $\delta^{13}C$ is not strictly linear, there is a close correspondence between increasing salinity and increasing $\delta^{13}C$ values. Accordingly we used the $\delta^{13}C$ values for marine organisms, in this case grey seals, as indicators of the prevailing Baltic Sea stage. The Skateholm I and II settlements coincided with the early Littorina stage of the Baltic – in other words, marine conditions were brackish but not as saline as later on, during the Littorina maximum. The faunal measurements also provide a valuable background for the interpretation of human stable isotope data.

Introduction

The Late Mesolithic cemeteries at Skateholm are vital to the study of the Swedish Stone Age. The Skateholm Stone Age complex, which is situated on the coast of Scania, Sweden (fig. 1), consists of a number of sites dating back to various phases of the Mesolithic and Neolithic (Larsson 1988a), the best-known of which are Skateholm I and Skateholm II, consisting of extensive Late Mesolithic cemeteries and adjoining settlement layers, located beside a former lagoon. The Skateholm I and II cemeteries were excavated by Lars Larsson in the early 1980s (Larsson 1988b), and settlement layers at both sites were also excavated in this connection. An additional limited excavation of Skateholm I settlement layers was undertaken by Ingrid Bergenstråhle in 1999 (Bergenstråhle 1999a).

Due to the gradually rising water level in the lagoon, the Skateholm II site became completely submerged during the later part of the Late Mesolithic, while the Skateholm I site, located on higher ground, was still habitable (Bergenstråhle 1999b; Larsson 2000). Skateholm II is the older of the two sites, judging from both radiocarbon dates and artefacts. There are as yet no reliable dates on bone from Skateholm II graves, but charcoal dates from settlement layers mainly fall between 5700 and 4700 cal BC (all dates from Larsson 1988c, calibrated at 2 sigma according to Stuiver et al. 1998). Bone samples from two Skateholm I graves have been dated to roughly 5300–5000 cal BC, whereas charcoal dates for graves suggest an additional burial phase prior to 4700 cal BC. The Skateholm I settlement layers, although overlapping chronologically with the later graves, seem slightly younger; and their charcoal dates end at 4300 cal BC. For an overview of the site, see Larsson (e.g. 1988b; 1988c; 1990; 1995; 2000) and Bergenstråhle (1999b).

The large number of interred humans, together with the amount of animal remains to be found in the settlement layers, make this site important – not only for the understanding of Mesolithic social organisation, but also for the study of resource utilization and diet. The location beside a lagoon could be considered favourable in the sense that there would have been high biodiversity as well as high productivity. A similar favourable

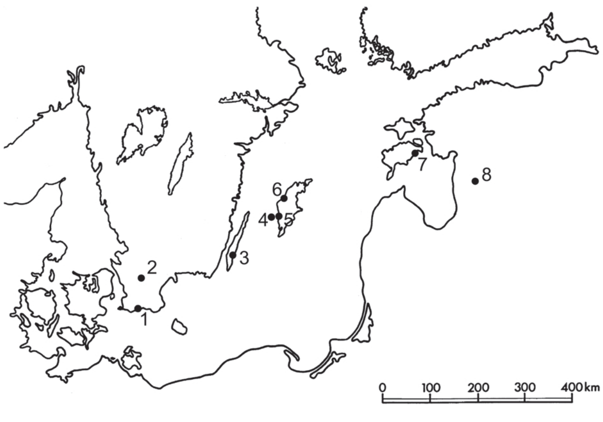

Figure 1. Map of the southern Baltic-Sea region with sites mentioned in the text. Skateholm is situated at the southern tip of Sweden. Legend: 1 – Skateholm, 2 – Ageröd, 3 – Alby, 4 – Stora Förvar, 5 – Ajvide, 6 – Viborgs kungsladugård, 7 – Asva, 8 – Zvejnieki.

Table 1. Stable isotope data on the samples which produced collagen. ~~Struck out~~ samples fall outside the prescribed quality ranges.

Lab code	Site	Structure /sqm	Common name	Species	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	C/N	% collagen	%C	%N
SKA 31	Skateholm I	104A	grey seal	*Halichoerus grypus*	–17.9	12.7	3.3	1.5	28.0	10.0
~~SKA 34~~	~~Skateholm I~~	~~114A~~	~~dog~~	~~*Canis familiaris*~~	~~–21.5~~	~~8.1~~	~~4.0~~	~~1.3~~	~~39.6~~	~~11.6~~
SKA 13	Skateholm II	x200, y225	grey seal	*Halichoerus grypus*	–18.6	13.7	3.2	2.3	34.9	12.8
SKA 12	Skateholm II	x200, y225	dog	*Canis familiaris*	–22.3	8.5	3.4	1.9	33.9	11.5
~~SKA 14~~	~~Skateholm II~~	~~x199, y224~~	~~dog~~	~~*Canis familiaris*~~	~~–16.7~~	~~11.1~~	~~3.8~~	~~1.2~~	~~29.0~~	~~9.0~~
SKA 19	Skateholm II	x199, y224	red deer	*Cervus elaphus*	–22.2	6.0	3.5	1.4	37.3	12.3
SKA 11	Skateholm II	x200, y225	wild cat	*Felis silvestris*	–19.7	8.7	3.5	2.5	34.3	11.3

choice of location can be seen in the case of the Mesolithic settlement at Alby, Öland, for example (Königsson et al. 1993).

An earlier investigation of resource utilization at Skateholm, primarily based on faunal analysis, pointed to a high utilization of fish from freshwater or brackish environments (Jonsson 1988). In order to assess the relative importance of different protein sources in the diet, Jonsson (1988:84) suggested that stable isotope analysis would be a useful tool, but only if more information about the complicated natural history of the Baltic Sea could be obtained.

Previous studies of the palaeoenvironment in the Skateholm lagoon area have drawn on investigations of pollen, macrofossils, diatoms and insects (various contributions by Lemdahl, Göransson, Gaillard and Håkansson in Larsson 1988b), but these were chiefly aimed at studying the development of the lagoon itself – not that of the Baltic Sea. Moreover, the analyses were mainly performed on samples from the Littorina ridge separating the lagoon from the sea. Thus, since sampling of the sites *per se* was not possible, the link with the graves and occupation layers was somewhat weak.

In the present study, stable isotope analysis is applied to animal bones from Skateholm I and II in order to shed light on the palaeoecology of the sites.

Material and methods

Stable isotope analysis of bone can produce data on the long-term protein intake of an individual. The analysis is performed on collagen, a protein that makes up the bulk of the organic part of bone. Stable isotopes of carbon ($\delta^{13}C$) are measured to distinguish between marine and terrestrial protein intake, and stable isotopes of nitrogen ($\delta^{15}N$) to indicate the level in the food chain.

In total, 45 faunal skeletal elements from excavations performed at Skateholm I and II in the 1980s and at the 1999 excavation of Skateholm I were sampled for collagen and a subsequent analysis was carried out of stable carbon and nitrogen isotopes. The purpose of the stable isotope analysis was two-fold: firstly, to produce data on that fauna potentially consumed by the people living at Skateholm, thus serving as a baseline for future analyses of human bone, and secondly, to establish isotopic end-values for Mesolithic Skateholm and look at possible chronological fluctuations during the Mesolithic. Since the stable carbon isotope value correlates with salinity (Strain & Tan 1979), $\delta^{13}C$ differences between Skateholm I and II would indicate differences in salinity.

The samples represent the following species (identifications by Leif Jonsson, cf. Jonsson 1988): red deer, wild boar, harbour porpoise, grey seal, ringed seal, wild cat, otter, red fox, wolf, dog, beaver, great black-backed gull, white-tailed eagle, pike and salmon/trout (table 1–2). All the samples were taken from unburned bones, except for the beaver samples (*Castor fiber*) which were from unburned teeth. From the Skateholm I site, 28 samples originated from settlement layers and two from graves (graves 9 and 46), whereas the Skateholm II site was represented by 13 samples from the settlement layers and two from a grave (grave XV).

Collagen was extracted according to Brown et al. (1988). Stable isotope ratios and carbon and nitrogen content were determined using an Optima Fison mass spectrometer run in continuous flow with a precision of <0.3‰ for both $\delta^{13}C$ and $\delta^{15}N$. The $\delta^{13}C$ and $\delta^{15}N$ values are calculated as $\delta=(R_{sample}/R_{standard}-1)\times1000‰$, where R is the $^{13}C/^{12}C$ or $^{15}N/^{14}N$ ratio respectively, expressed relative to the standards, PDB limestone for carbon and atmospheric N_2 for nitrogen.

Results

The bones were in general very poorly preserved, so that only five samples out of 45 produced well-preserved collagen, as indicated by the C/N ratio, carbon and nitrogen content, and yield (for a discussion of collagen quality indicators, see van Klinken 1999 and references cited therein). All five samples derive from Lars Larsson's excavations of settlement layers at Skateholm I and II in the 1980s (table 1). Neither bones from the graves, nor bones from the 1999 excavation produced any collagen. Two samples (SKA 14, SKA 34) yielded "collagen" that was either contaminated or diagenetically altered, as indicated by C/N ratios outside the acceptable range of 2.9–3.6 (DeNiro 1985) (table 1), whereas 38 samples produced insufficient amounts of collagen or none at all (table 2). Further discussion will concern only the five samples that met the quality requirements.

There was only one sample of sufficient quality from Skateholm I, a grey seal (*Halichoerus grypus*), whereas Skateholm II was represented by an additional grey seal, a dog (*Canis familiaris*), a red deer (*Cervus elaphus*) and a wild cat (*Felis silvestris*) (table 1,

Lab code	sqm/structure	Common name	Species
Skateholm I			
SKA 21	x106, y126	red deer	*Cervus elaphus*
SKA 16	x106, y126	wild boar	*Sus scrofa*
SKA 29*	x101.5, y118.5	wild boar	*Sus scrofa*
SKA 33*	x103.5, y119–122	wild boar	*Sus scrofa*
SKA 43	x104, y124	wild boar	*Sus scrofa*
SKA 17	x103, y122	grey seal	*Halichoerus grypus*
SKA 32*	x103.5, y119–122	grey seal	*Halichoerus grypus*
SKA 48	x104, y124	grey seal	*Halichoerus grypus*
SKA 49*	x103.5, y119–122	grey seal	*Halichoerus grypus*
SKA 50*	x104, y118	grey seal	*Halichoerus grypus*
SKA 08	x103, y122	ringed seal	*Pusa hispida*
SKA 30*	x103.5, y120	otter	*Lutra lutra*
SKA 07	x103, y122	red fox	*Vulpes vulpes*
SKA 10	x103, y122	wolf	*Canis lupus*
SKA 09	x106, y126	dog	*Canis familiaris*
SKA 35*	x103.5, y119–122	dog	*Canis familiaris*
SKA 51¤	A15 (grave 9)	dog	*Canis familiaris*
SKA 06	x102, y125	beaver	*Castor fiber*
SKA 25	x104, y122	beaver	*Castor fiber*
SKA 26	x103, y122	beaver	*Castor fiber*
SKA 27	x102, y125	beaver	*Castor fiber*
SKA 22	x104, y124	white-tailed eagle	*Haliæetus albicilla*
SKA 18	x106, y126	great black-backed gull	*Larus marinus*
SKA 15	x103, y122	pike	*Esox lucius*
SKA 37	x104, y124	pike	*Esox lucius*
SKA 38	x104, y124	pike	*Esox lucius*
SKA 39	x104, y124	pike	*Esox lucius*
SKA 20	x104, y124	salmon/trout	*Salmo* sp.
Skateholm II			
SKA 23	x199, y226	wild boar	*Sus scrofa*
SKA 42	x200, y213	wild boar	*Sus scrofa*
SKA 46	x200, y224	wild boar	*Sus scrofa*
SKA 36	x200, y212	harbour porpoise	*Phocoena phocoena*
SKA 47	x200, y217	grey seal	*Halichoerus grypus*
SKA 40	x199, y225	dog	*Canis familiaris*
SKA 44¤	A33 (grave XV)	dog	*Canis familiaris*
SKA 45¤	A33 (grave XV)	dog	*Canis familiaris*
SKA 24	x199, y220	beaver	*Castor fiber*
SKA 41	x200, y225	pike	*Esox lucius*

*Table 2. Samples which did not produce any collagen, sorted according to site and species. The samples were from settlement layers unless stated, *=from the 1999 excavation, ¤=from a grave.*

fig. 2). Because of the limited number of samples, it is impossible to draw any conclusions regarding chronological change, i.e. differences between Skateholm I and Skateholm II. The isotopic data must be treated with caution, since each species is represented by only one individual, or, in the case of grey seals, by two individuals not contemporary with each other. Nevertheless, some important conclusions can be drawn on the stable isotope ecology of the lagoon.

The δ^{13}C for the red deer was –22.2‰, and the δ^{15}N was 6.0‰. Both values are consistent with the fact that the red deer is a completely terrestrial herbivore. The stable nitrogen isotope value is enriched by some 3‰ for every trophic level (Minagawa & Wada 1984), and 6‰ is thus a typical value for a species feeding on plants. The δ^{13}C value also provides the terrestrial end-value for Skateholm.

It is interesting that the dog has a similar value, –22.3‰, hence pointing to a complete lack of marine influence in its diet. As for trophic level, the δ^{15}N value, 8.5‰, indicates, as expected, that the dog was carnivorous or omnivorous rather than herbivorous.

As seals are top-level marine predators, we would expect them to represent marine end-values for carbon isotopes and to have high nitrogen isotope values. The two grey seals, one from each site (Skateholm I: –17.9‰, 12.7‰; Skateholm II: –18.6‰, 13.7‰), differ in δ^{13}C by 0.7‰, and in δ^{15}N by 1.0‰. These differences are small, however, and should not be interpreted as indicative of any chronological trend. Nevertheless, if these data were to be supported by more measurements, the negative correlation between nitrogen and carbon in our seal samples could possibly be explained by a lower salinity in the older Skateholm II samples.

The wild cat is a carnivore, known to have a diet consisting mainly of small rodents. The δ^{15}N of 8.7‰ does not contradict such an interpretation, but the δ^{13}C value, –19.7‰, is interme-

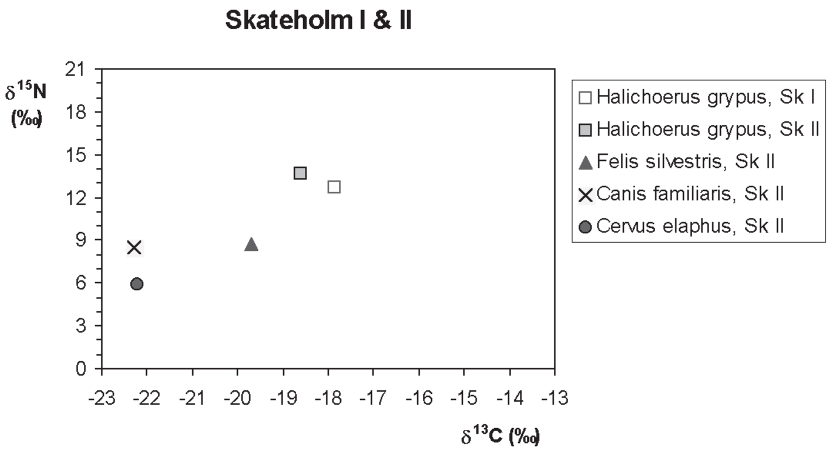

Figure 2. Stable carbon and nitrogen isotope values for the fauna of Skateholm I and II.

diate with regard to the terrestrial and marine end-values, so there must have been an input of marine species in the diet as well. Although it is more likely that the cat was hunted for its fur than for its meat, the stable isotope data nonetheless help us in clarifying the stable isotope ecology of the lagoon.

Discussion and conclusion

The span from terrestrial to marine $\delta^{13}C$ values at Skateholm ranges between around –22‰ and –18‰. This certainly does not rule out the possibility that humans buried at Skateholm could have $\delta^{13}C$ values outside that range. In fact, a previous study by Lidén & Nelson (1994), showed the two young individuals buried in grave 47 at Skateholm I to have far more marine (i.e. less negative) $\delta^{13}C$ values: –16.3‰ and –16.2‰ respectively. This indicates that they derived a considerable part of their protein from an entirely marine environment, and not from the brackish Baltic Sea.

Although the correlation between salinity and $\delta^{13}C$ is not strictly linear, there is a close correspondence between increasing salinity and increasing $\delta^{13}C$ values (Strain & Tan 1979). Since the various stages of the Baltic Sea also entailed changing salinity, the $\delta^{13}C$ values for marine organisms such as seals can be used as indicators of the prevailing stage of the Baltic. Analysis of stable isotopes from one species with a known ecology, in this case the grey seal, can thus be a useful complement to other methods when reconstructing the salinity in a specific environment. This can be illustrated in a plot (fig. 3) of the $\delta^{13}C$ values for grey seals from various archaeological sites in the Baltic region against time, ranging from the Early Mesolithic to the Bronze Age. The increasing salinity, as indicated by increasing $\delta^{13}C$, is clearly visible, and the corresponding change in the Baltic from the Ancylus Lake to the Littorina Sea is consequently reflected in the plot. As is evident from the present seal isotope values, the Skateholm I and II settlements coincided with the early Littorina stage of the Baltic – in other words, conditions that were brackish but not as saline as later on, during the Littorina maximum.

Some previous stable isotope studies have put forward the hypothesis that dogs could be used as surrogates for humans, since they allegedly had the same diet (Noe-Nygaard 1988; Katzenberg 1989; Clutton-Brock & Noe-Nygaard 1990; Day 1996; Cannon et al. 1999). A recent study of dogs at the Zvejnieki Stone Age complex in Latvia (Eriksson & Zagorska 2002), however, has demonstrated that this assumption is simply not valid. Dogs could have had a number of different roles in human society, and these would have affected their diets, so that dogs are not likely to have had either homogenous diets within a particular community or the same diet as humans.

The numerous roles of the dog at Skateholm I and II are further demonstrated by the many different manners of dog deposition. Apart from scattered bones in the cultural layers, dogs were also buried in separate graves, with or without grave goods, or deposited in human graves, complete or in parts. The Skateholm II dog analysed here, with its completely terrestrial stable isotope signature, should not be interpreted as an indication of human diet at the site. The previously published $\delta^{13}C$ values for humans, although from Skateholm I, hint at a completely different scenario, and it is hoped that future analyses of human remains from the Skateholm cemeteries will help to clarify this issue.

The present study has demonstrated the importance of making background analyses of fauna when interpreting stable isotope data applying to humans. At a site like Skateholm in particular, with a fairly complicated natural history, it is necessary to elucidate the stable isotope ecology in order to arrive at accurate conclusions.

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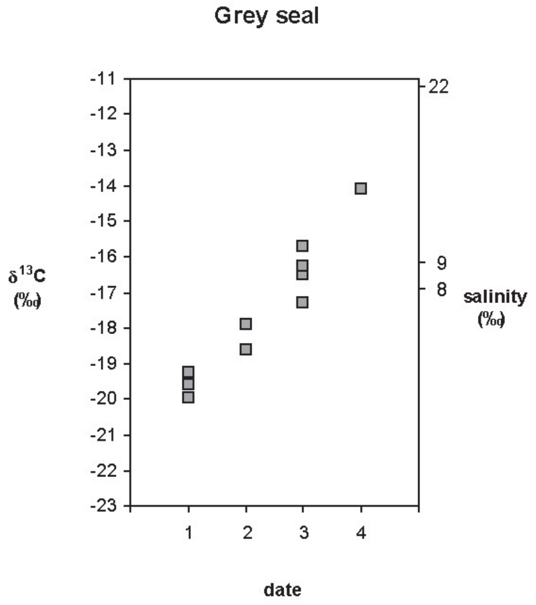

Figure 3. Stable carbon isotope data on grey seal from various Baltic Sea sites plotted against time. Salinity increases with increasing $\delta^{13}C$ values, and also from the Early Mesolithic to the Neolithic, i.e. from the Ancylus Lake to the Littorina Sea. Legend (dates of sites): ***1*** *– Early Mesolithic (Viborgs kungsladugård, Ageröd I:HC, Stora Förvar),* ***2*** *– Late Mesolithic (Skateholm I and II),* ***3*** *– Middle Neolithic (Västerbjers, Ajvide),* ***4*** *– Bronze Age (Asva). Grey seal data from Lõugas et al. 1996, Lindqvist & Possnert 1997, the present study, and Eriksson unpublished data. The salinity data are based on $\delta^{13}C$ values for modern cod (Gadus morrhua), caught at different salinities in the Baltic and the Kattegat/Skagerrak (Angerbjörn et al. ms). The values should only be seen as indicative and not as absolute.*

References

Angerbjörn, A., Börjesson, P., & Brandberg, K. Ms. Predicted regional origin of harbour porpoises based on stable isotopes.

Bergenstråhle, I.(ed.) 1999a. Rapport över seminariegrävning på Skateholm I, vt 1999. St. Beddinge 7:4, Tullstorps sn, Trelleborgs kommun (fornlämning Tullstorp RAÄ 22). Arkeologiska institutionen, Lunds universitet.

Bergenstråhle, I. 1999b. Skateholm, a late mesolithic settlement in southern Scania, in a regional perspective. In A. Thévenin (ed.): *L'Europe des derniers chasseurs. Épipaléolithique et Mésolitique*, pp. 335–340. Documents préhistoriques. Paris.

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

Cannon, A., Schwarcz, H. P. & Knyf, M. 1999. Marine-based subsistence trends and the stable isotope analysis of dog bones from Namu, British Columbia. *Journal of Archaeological Science* 26, 399–407.

Clutton-Brock, J. & Noe-Nygaard, N. 1990. New osteological and C-isotope evidence on Mesolithic dogs: Companions to hunters and fishers at Star Carr, Seamer Carr and Kongemose. *Journal of Archaeological Science* 17, 643–653.

Day, S. P. 1996. Dogs, deer and diet at Star Carr: A reconstruction of C-isotope evidence from early Mesolithic dog remains from the Vale of Pickering, Yorkshire, England. *Journal of Archaeological Science* 23, 783–787.

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

Eriksson, G. & Zagorska, I. 2002. Do dogs eat like humans? Marine stable isotope signals in dog teeth from inland Zvejnieki: *Mesolithic on the Move (Proceedings of the 6th International Conference on The Mesolithic in Europe)*. Oxbow Monograph. Oxford. In press.

Jonsson, L. 1988. The vertebrate faunal remains from the Late Atlantic settlement Skateholm in Scania, South Sweden. In L. Larsson (ed.): *The Skateholm Project: I. Man and Environment*, pp. 56–88. Acta Regiae Societatis humaniorum litterarum Lundensis. Lund.

Katzenberg, M. A. 1989. Stable isotope analysis of archaeological faunal remains from Southern Ontario. *Journal of Archaeological Science* 16, 319–329.

Königsson, L-K., Königsson, E. S., Bendixen, E., & Possnert, G. 1993. Topography and chronology of the Alby stone age settlement on south-eastern Öland, Sweden. In Arwidsson et al. (eds.): *Sources and resources, Studies in honour of Birgit Arrhenius*, pp. 13–39. PACT. Rixensart.

Larsson, L. 1988a. The Skateholm Project: Late Mesolithic settlement at a South Swedish lagoon. In L. Larsson (ed.): *The Skateholm Project: I. Man and Environment*, pp. 9–19. Acta Regiae Societatis humaniorum litterarum Lundensis. Lund.

Larsson, L. (ed.) 1988b. *The Skateholm Project: I. Man and Environment* (Acta Regiae Societatis humaniorum litterarum Lundensis 79). Lund.

Larsson, L. 1988c. Late Mesolithic settlements and cemeteries at Skateholm, Southern Sweden. In C. Bonsall (ed.): *The Mesolithic in Europe: Papers presented at the Third International Symposium*, pp. 367–378. Edinburgh.

Larsson, L. 1990. Dogs in fraction – symbols in action. In P. M. Vermeersch & P. V. Peer (eds.): *Contributions to the Mesolithic in Europe: Papers presented at the Fourth International Symposium "The Mesolithic in Europe", Leuven 1990*, pp. 153–160. Leuven.

Larsson, L. 1995. Man and sea in Southern Scandinavia during the Late Mesolithic: The role of cemeteries in the view of society. In A. Fischer (ed.): *Man and Sea in the Mesolithic: Coastal settlement above and below present sea level (Proceedings of the International Symposium, Kalundborg, Denmark 1993)*, pp. 95–104. Oxbow Monograph. Oxford.

Larsson, L. 2000. Cemeteries and mortuary practice in the Late Mesolithic of Southern Scandinavia. In V. Lang (ed.): *De temporibus antiquissimis ad honorem Lembit Jaanits*, pp. 81–102. Muinasaja Teadus (*Research into ancient times*). Tallinn.

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

Lindqvist, C. & Possnert, G. 1997. The subsistence economy and diet at Jakobs/Ajvide and Stora Förvar, Eksta parish and other prehistoric dwelling and burial sites on Gotland in long-term perspective. In G. Burenhult (ed.): *Remote Sensing, vol. I*, pp. 29–90. Theses and Papers in North-European Archaeology. Stockholm.

Lõugas, L., Lidén, K. & Nelson, D. E. 1996. Resource utilization along the Estonian coast during the Stone Age. In T. Hackens, S. Hicks, V. Lang, U. Miller & L. Saarse (eds.): *Coastal Estonia: Recent Advances in Environmental and Cultural History*, pp. 399–420. PACT. Rixensart.

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

Noe-Nygaard, N. 1988. $\delta^{13}C$-values of dog bones reveal the nature of changes in Man's food resources at the Mesolithic–Neolithic transition, Denmark. *Chemical Geology (Isotope Geoscience Section)* 73, 87–96.

Strain, P. M. & Tan, F. C. 1979. Carbon and oxygen isotope ratios in the Saguenay Fjord and the St Lawrence Estuary and their implications for paleoenvironmental studies. *Estuarine and Coastal Marine Science* 8, pp. 119–126.

Stuiver, M., Reimer, P. J., Bard, E., Beck, J. W., Burr, G. S., Hughen, K. A., Kromer, B., McCormac, G., van der Plicht, J. & Spurk, M. 1998. INTCAL98 Radiocarbon Age Calibration, 24,000–0 cal BP. *Radiocarbon* 40, pp. 1041–1083.