Early Human Impact on Megamolluscs

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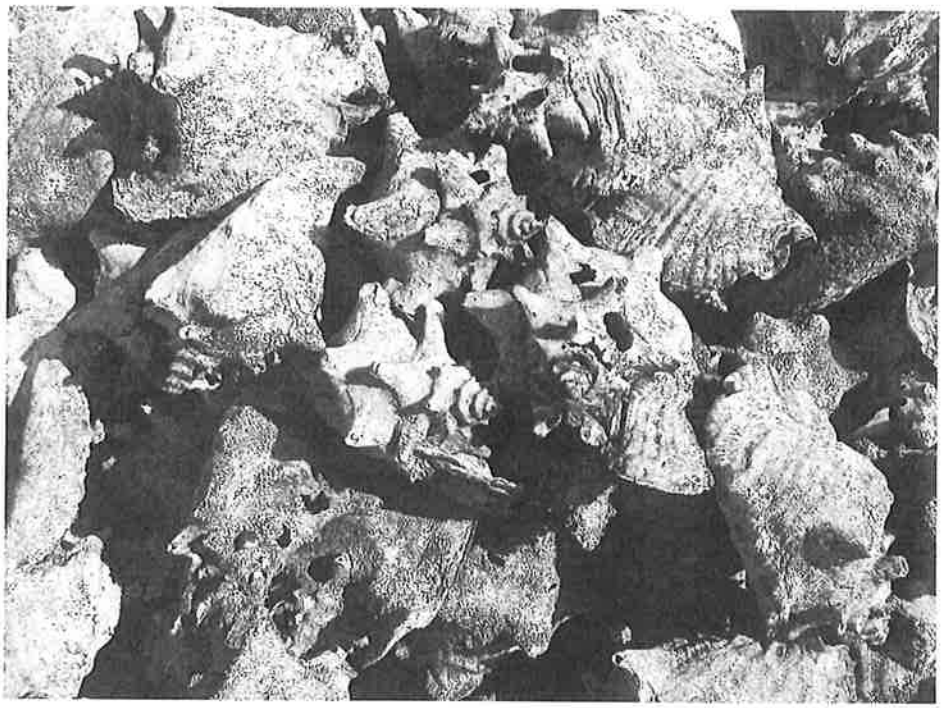

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Shell Middens (*"Køkkenmøddinger"*): The Danish Evidence

SØREN H. ANDERSEN[1]

Abstract
This paper is a review of research on Stone Age shell middens (Danish: "Køkkenmøddinger") in Denmark. A brief survey on the history of research and excavation technique is given, followed by a definition of what a shell midden is in a Danish/North European context. The distribution, form and structure of such sites, chronology, formation processes, contents, and cultural associations, are discussed. An account of different types of "Køkkenmøddinger" is put forward, and a special type of middens, the so - called "Stratified shell middens", is described in more detail, because of their relevance for information on the oldest agriculture in Southern Scandinavia. A section of the paper deals with settlement structures and a discussion on the issue of whether these middens were the proper settlements. It is concluded that they are not a unique type of coastal settlement but represent coastal, home - base settlements characterised by a dominance of shellfish in the cultural deposits. This is the only respect in which they differ from the rest of the coastal habitation system. Shell midden sites seem to flourish in periods characterised by a rich marine biotope, and coastal habitation can be seen as a direct reflection of variations/changes in the marine biotope. Finally, some reflections on the future of the Danish "Køkkenmøddinger" and køkkenmødding research are formulated.

Key words: Danish Køkkenmøddinger, Danish Stone Age, shell middens

Figure 1. The second "kitchen midden commission" excavating at Ertebølle (*locus classicus*) in Northwestern Denmark in 1893. The excavation was performed with a square meter grid and in 20 cm thick layers; all animal bones and other types of cultural debris was recorded. Photo: The National Museum of Denmark.

History of research

Research on Danish shell middens (*Køkkenmøddinger* or kitchen middens) goes back to 1831, when the first Stone Age midden (Krabbesholm) was recognized. Since then, the research has been characterized by a fruitful collaboration between the natural sciences and archaeology, and formalized in the so called "kitchen midden commissions" (1848, 1893, and 1937) (Figure 1). Using new excavation techniques, theoretical frameworks, ethnographic information and ^{14}C-dating, kitchen midden research was resumed in the 1970s by the so-called Fourth Commission (Fischer and Kristiansen 2002).

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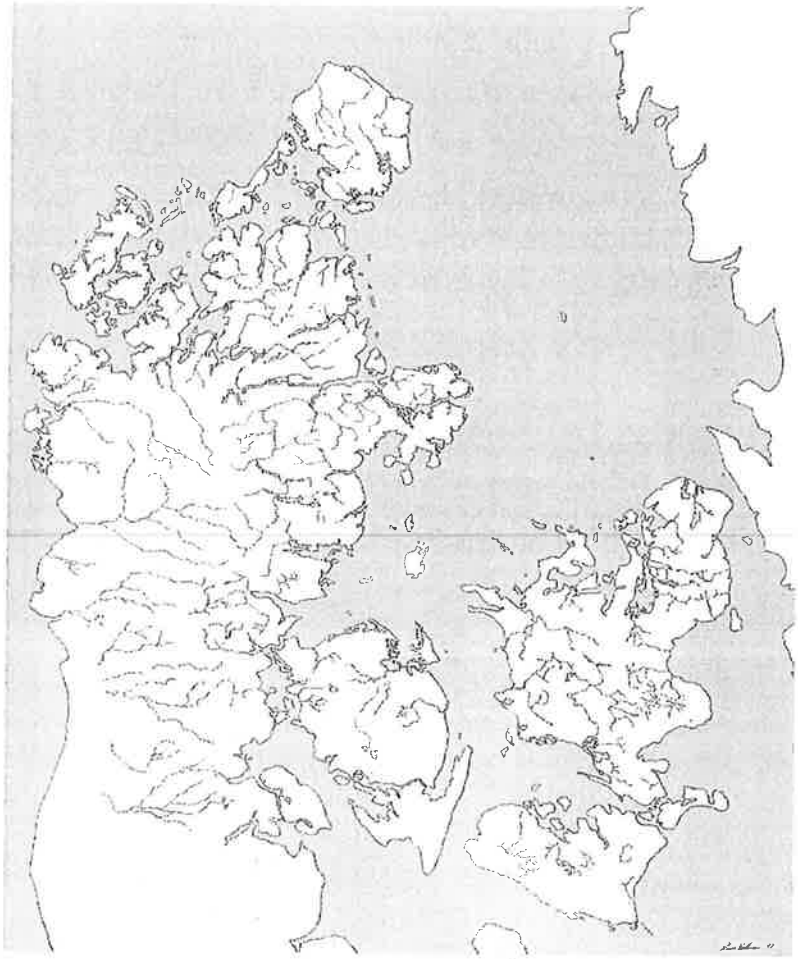


Figure 2. The land – sea configuration of Denmark ca. 6500 – 2000 cal. B.C.

In the 1800s it was already recognized that the Danish Stone Age shell middens belong to two different periods: the Mesolithic, 9000-3950 cal B.C. and the Neolithic, 3950-1700 cal B.C. Today we know that shell middens are not exclusively a Stone Age phenomenon; quite contrary, they are known from most prehistoric periods, and large shell middens are numerous from the Early Iron Age (500 cal B.C. - A.D. 400). The number and sizes of Danish middens vary through the prehistory. Because of the historical development in the kitchen midden research, most attention has been focused on the Stone Age middens of which we today have a very detailed knowledge compared to most other regions of the world; the middens from later periods have been much less in focus.

Denmark in the prehistory

The postglacial rise in temperature resulted in a steep increase in world sea level that changed the land-sea configuration and transformed Denmark during the Atlantic Period (6000-4000 cal B.C.) into an archipelago with many islands, fjords, bays, estuaries, intertidal zones and strand flats. The coastal region is, therefore, characterised by a constant change between land and sea, resulting in a series of different coastal biotopes of which the estuaries, strand flats and intertidal areas are among the most biologically productive (Odum 1971). Add to this the fact that generally the Danish waters are very shallow (0 – 30/50 m) and the coasts are made up of "soft" sediments such as clay, sand and gravel. As the Danish coastline has a length of ca. 7300 km and nearly all parts of Denmark are located within less than 10-20 km from one or several coastlines, the whole country is, and has for the last 7000-8000 years, been coastally related (Figure 2). This is an essential factor to have in mind when analysing and trying to understand the Danish prehistory. The Atlantic sea was 2-3 °C warmer, more salty, nutritious and possibly also with higher tidal amplitude (ca. 2.5 m) than today and all together produced a very rich, marine food chain and many oyster banks (Nielsen 1938; Iversen 1967). However, the salinity, the local topography, the temperature and the tidal exchange of seawater have changed several times during the prehistory, affecting the marine environment and its productivity. Today, the salinity and sea temperature are lower than in the prehistory and the oyster is only found in a small area in the northwestern part of Denmark.

What is a Danish kitchen midden?

The term "shell midden" has been used all over the world, but in different ways and with a different content. A Danish *Køkkenmødding* is defined as a cultural deposit in which at least 50% of the volume consists of shells or

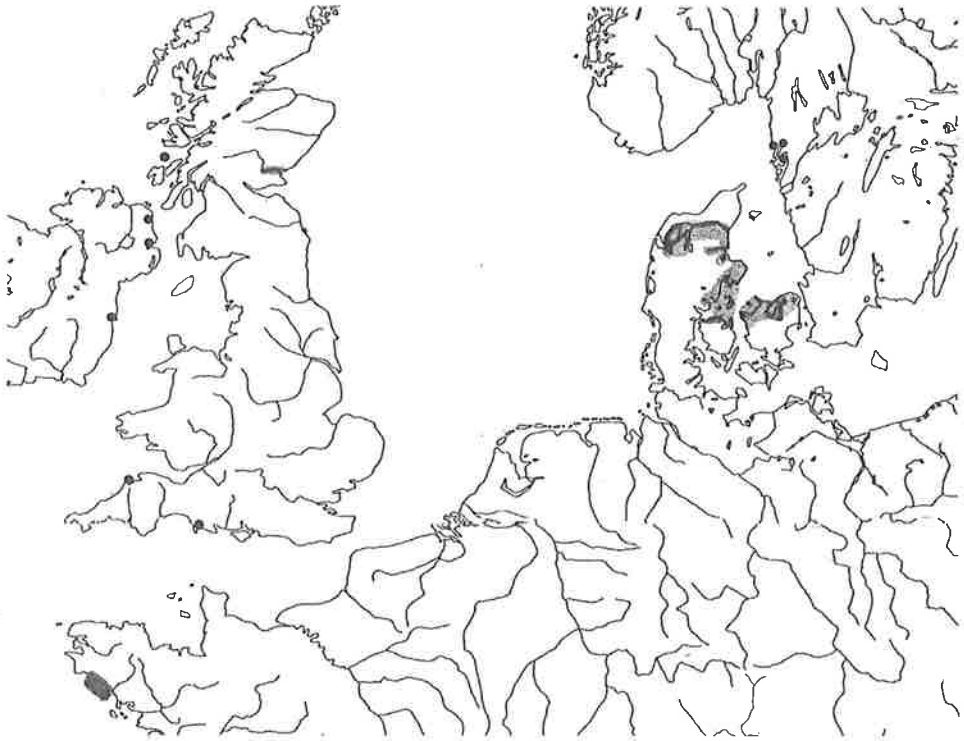


Figure 3a. The distribution of Stone Age *køkkenmøddinger* in Northern Europe.

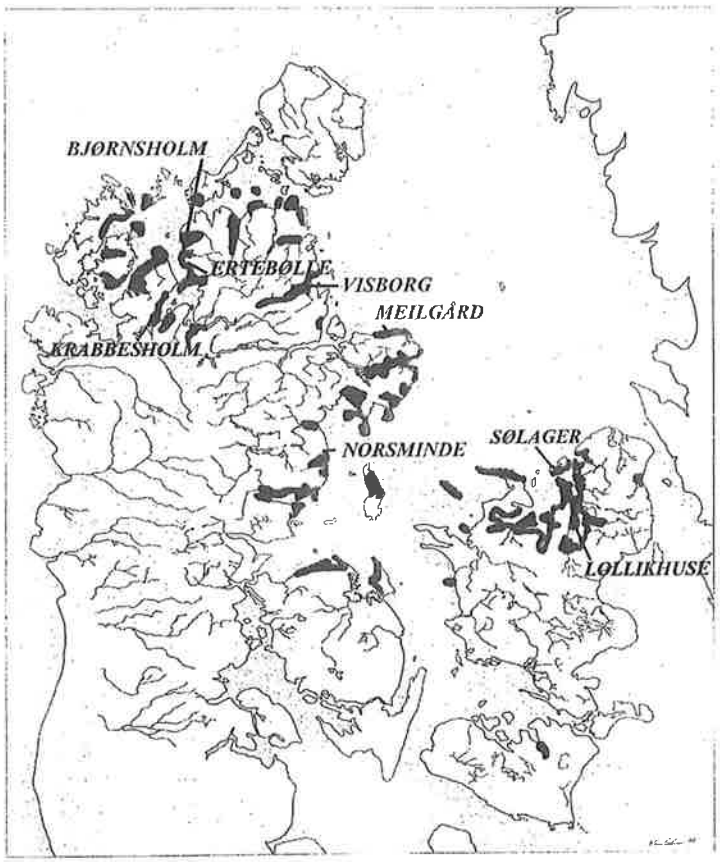


Figure 3b. The distribution of Stone Age shell middens in Denmark. They are only found in the North – Northeastern part of the country. The position of some of the famous sites is indicated.

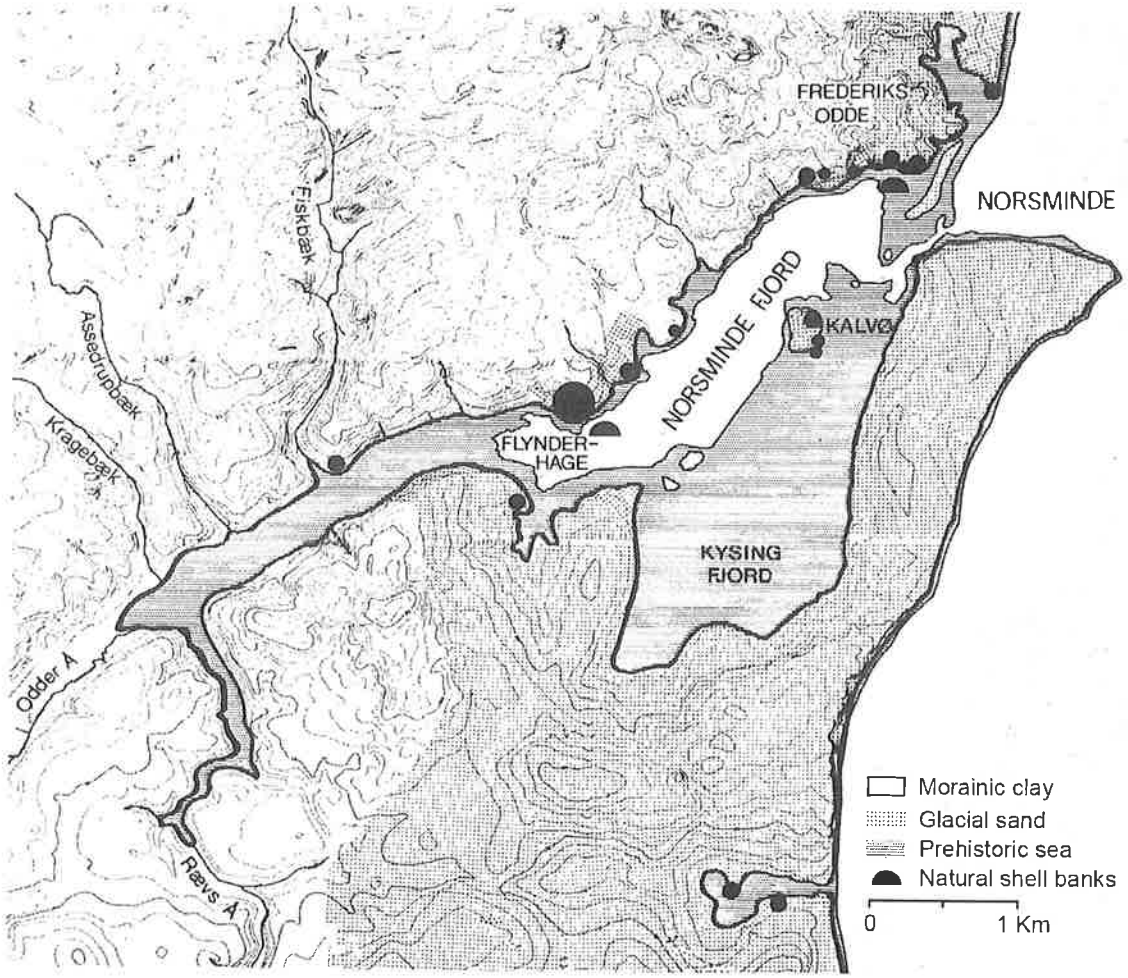


Figure 4. The Norsminde fjord in Eastern Jutland with all Late Mesolithic (Ertebølle culture) with all coastal settlements indicated. The largest settlement is positioned in the centre of the fjord and the smaller sites are found in the periphery. Kitchen middens as well as coastal sites without shell deposits are found interspersed with each other along the coastline. In many Danish fjords there are more coastal settlements without shell deposits than *køkkenmøddinger*. Observe the position of two "natural" shell banks out in the fjord just in front of two shell middens. Morainic clay. Glacial sand. Prehistoric sea. Natural shell banks.

their fragments, and which forms a continuous horizon exceeding at least 10 m^2. If the deposit does not fall into this category, but still contains shells, the site is called *a shell bearing site* or *a site with scattered shells* or *isolated shell heaps* (Andersen 2000: 362). The kitchen middens are also characterized by the narrow taxonomic range of marine molluscs, which only include 4 - 5 species compared to the natural, marine population and, also, by the trend towards large (and old) individuals.

When studying prehistoric shell middens it is very important to compare these with natural shell banks, as the latter reflect the entire marine ecosystem. A study of such banks produces essential clues to the understanding and interpretation of the "non – cultural" variations in the composition of the *Køkkenmøddinger*. Especially important is the study of the environmental constraints upon the mollusc species prior to human interaction and the exploitation of the banks. In Denmark, there are many hundreds of natural shell banks and marine sediments with shell horizons but, unfortunately, only very few have been scientifically investigated and dated, such as Ertebølle (Petersen 1987: 79) (Figure 5). This is an essential issue for future shell midden research in Denmark.

Distribution

Denmark is the country in Northern Europe with the highest concentration of shell middens (Figure 3a+3b). Today we have a record of ca. 400 - 500 sites preserved from the Stone Age and a similar number from the Iron Age. Generally speaking, all shell middens are found in association with the prehistoric coastlines, but in Denmark they have a restricted geographical distribution. The Stone Age middens are found in northern - northeastern Denmark only, while the Iron Age kitchen middens are more evenly distributed along the Danish and north German coastlines (Figure 8). The highest number of Stone Age shell middens is in western Denmark, where also the largest and most famous sites, such Ertebølle (*locus classicus*), Meilgaard, Bjørnsholm and Krabbesholm, are located (Figure 3b). Therefore, this is also the region where we have had the most comprehensive and detailed midden research.

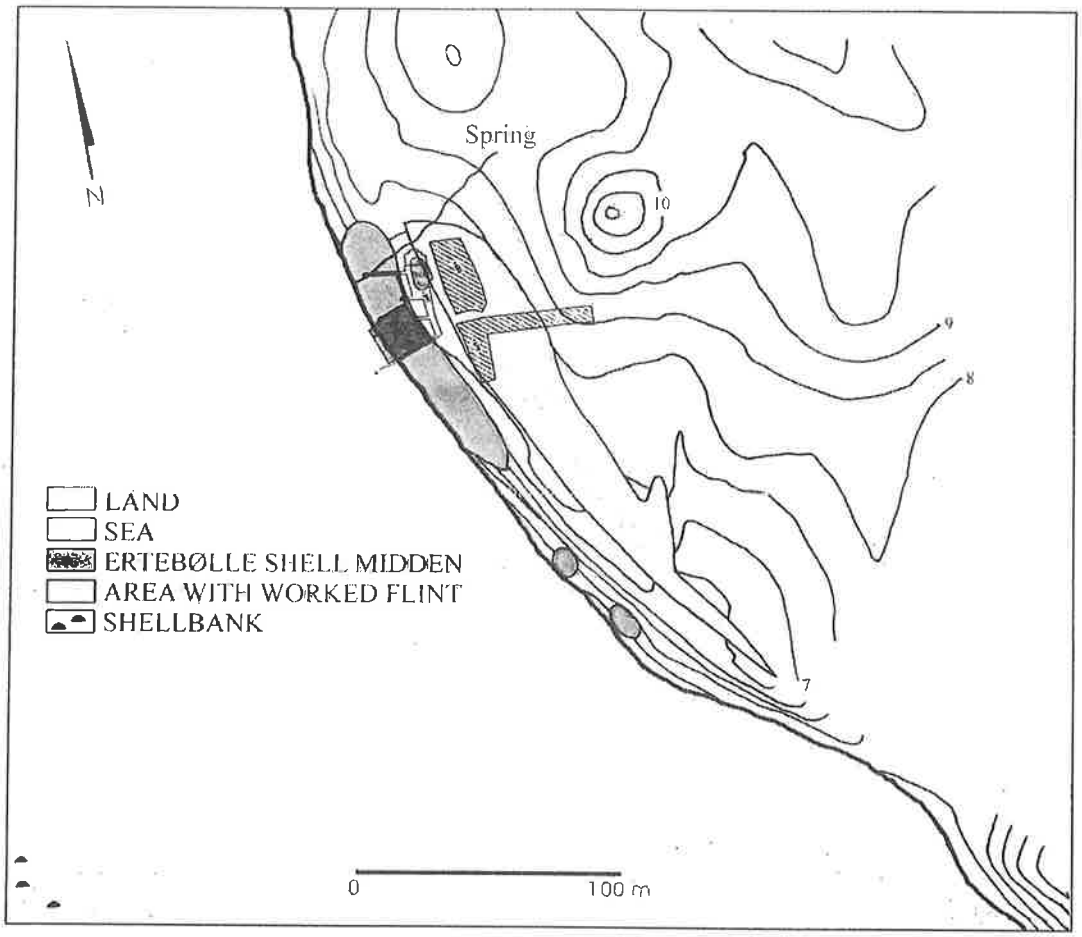


Figure 5. The outline of the Ertebølle shell midden (*locus classicus*) (shaded); further to the south there is two smaller shell middens. To the rear of the site there is an extensive area with worked flint – a habitation area without shell deposits (light shaded). C. 300 ms to the southwest in the marine sediments off the kitchen midden natural shell horizons have been recorded and ^{14}C dated as being contemporary with the midden. The excavated sections and areas are indicated and shaded dark grey and hatched.

The Danish shell middens are found in areas with a high resource biomass, especially in estuaries and intertidal zones. These types of maritime environment are characterised by a greater ecological stability than corresponding terrestrial biomes within the same latitudinal zone (Dunbar 1960). A preferred location of the Mesolithic kitchen middens was at the opening of, or, at the very centre of an estuary. Shell middens can be found together with contemporary, coastal settlementswithout shell deposits (Figure 4). The middens can be situated very close to each other, in some cases with only a distance of a few hundred meters between them. The large sites are found evenly spread at a distance of 5 to 10 km between them. In areas well defined topographically, such as fjords, only one of the middens will be large; this midden is usually surrounded by a number of smaller midden sites, as in Norsminde Fjord site (Figure 4).

The distribution of the Mesolithic shell middens along the coastlines clearly reflects a linear settlement pattern and social organisation. A consequence of such a settlement pattern and of the nature of maritime resources is that maritime collecting is best undertaken from a single location to take advantage of several resources, according to a "logistical collecting" behaviour (Binford 1980). This is well documented in the settlement pattern of the Danish Ertebølle culture, which clearly reflects "central-place foraging" behaviour. Coastal settlements, then, tend to be optimally located.

In Denmark, new investigations seem to indicate that the distribution of *Køkkenmøddinger* is closely connected with the local environment. The shell middens are located close to places where mollusc banks developed during the Atlantic – Subboreal periods. Therefore, for a coastal settlement to become a *Køkkenmødding* it depended on the presence of natural shell banks within an "economic" distance of the settlement, as in Ertebølle (Figures 4 and 5). The shellfish represents a highly concentrated resource, easily collectable by all segments of the population and, finally, the banks can withstand a culling rate of ca. 14 %.

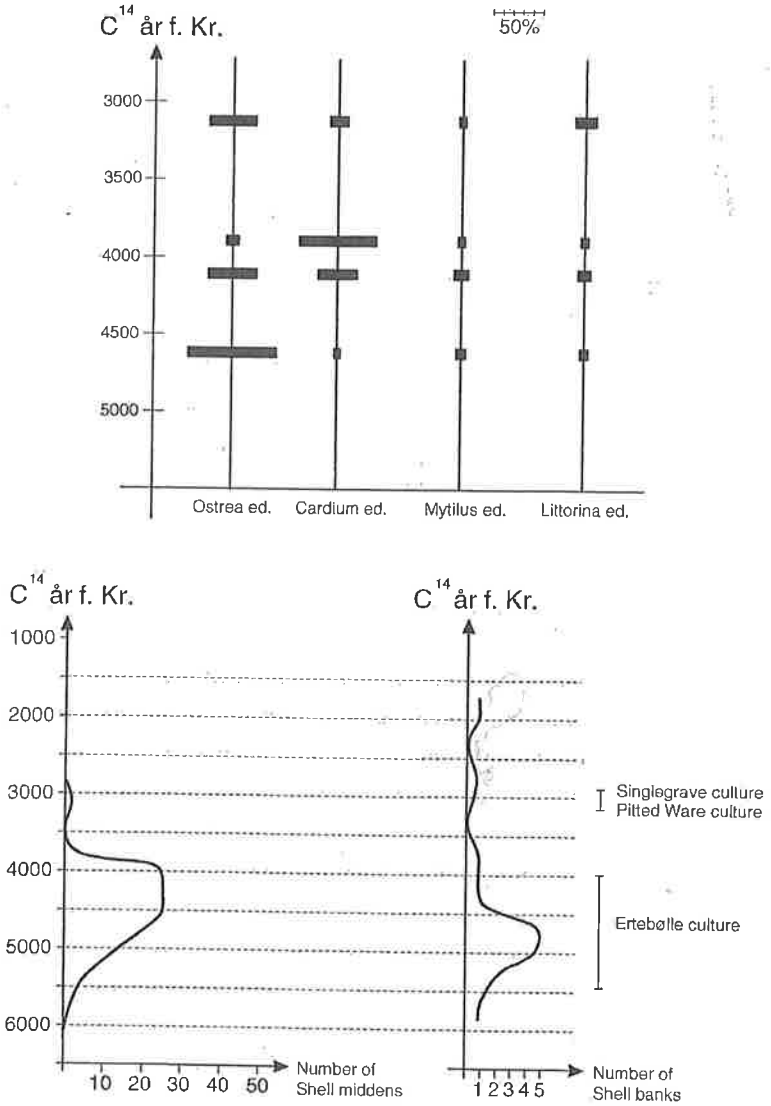


Figure 6. A) Relative frequency of mollusks and snails in the Danish Stone Age shell middens. B) Frequency of the Danish kitchen middens and "natural" shell banks through the Stone Age.

Stone Age shell middens (5600-1700 cal B.C.)

The oldest kitchen middens in Denmark date back to ca. 5600 cal B.C. (i.e. the late Kongemose Culture) and, from that time onward, there is a nearly continuous series of shell middens through the Stone Age (Figure 6+7). However, after the earliest appearance of middens (5600-5400 cal B.C.) their number decrease, and the majority of Stone Age kitchen middens belong to the period ca. 4400-4200 cal B.C., i.e. the Late Atlantic period and the Ertebølle culture of Southern Scandinavia (5400-4000 cal B.C.). The most famous Mesolithic shell middens, e.g. Meilgaard and Ertebølle, all belong to this period. In Southern Scandinavia, the transition from the Mesolithic to the Early Neolithic took place ca. 3950 cal B.C., and several middens cover this transition by having cultural horizons from both periods. Kitchen middens are also very common from the first 400-500 years of the Early Neolithic, ca. 4000-3500 cal B.C. Later, in the Neolithic, ca. 3500-2800 cal B.C., there are still shell middens, e.g. Fannerup (Eriksen 1984), but their number and size decrease.

The centuries from ca. 2800 to 2500 cal B.C. is a period with a slight increase in the number of kitchen middens. However, they are very few in number and much smaller in size than shell middens from earlier Stone Age periods, e.g. Kalvø in Norsminde Fjord, which only measured 8 x 8 m and had a layer ca. 40 cm thick (Andersen 1983: 71). After that period, shell middens disappear as a type of Stone Age coastal site and, from the Late Neolithic(2300-1700 cal B.C.), shellfish is only found as small piles in the settlements, e.g. Myrhøj (Jensen 1973: 78). However, despite the disappearance of actual shell middens, the gathering of marine molluscs obviously continued, but on

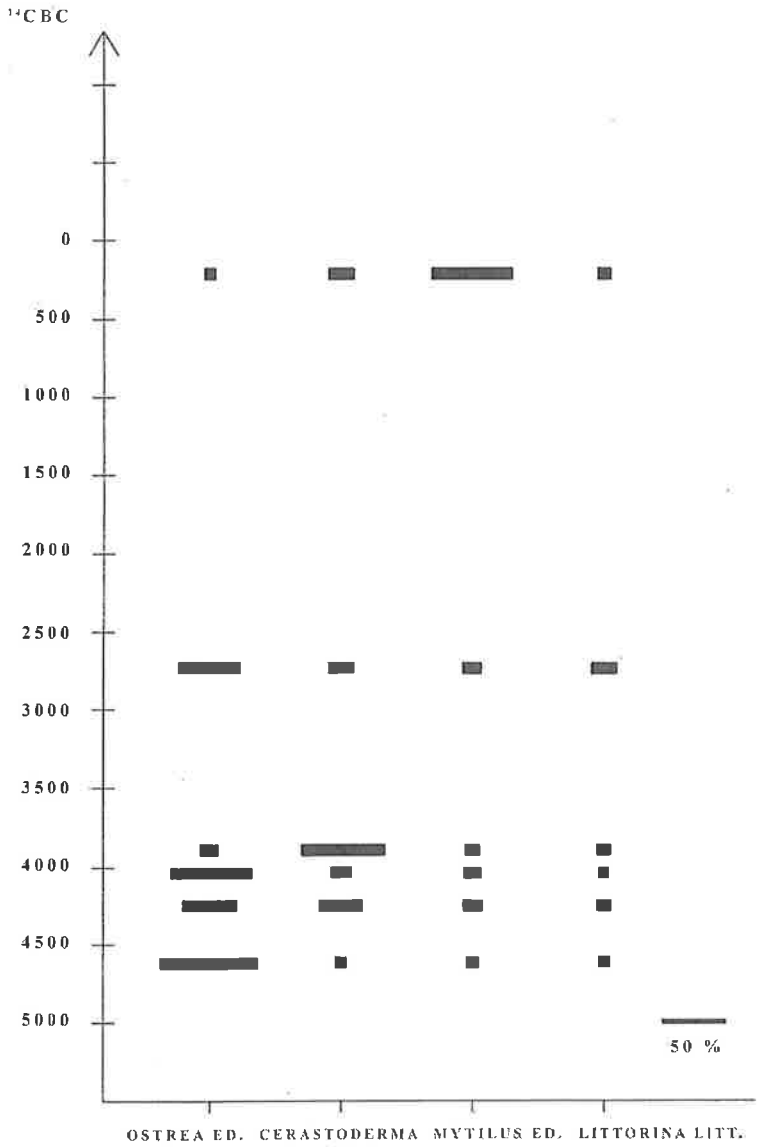


Figure 7. Diagram of the relative frequency of the marine mollusc species in Danish *køkkenmøddinger* from ca. 5000 – 250 cal. B.C. from the Late Mesolithic to the Early Iron Age (Cille Krause).

a much smaller scale. Despite the fact that many Danish *Køkkenmøddinger* demonstrate very long occupation sequences during the Stone Age, it is worth observing that no middens so far show shell gathering through *the whole* Late Mesolithic and Neolithic of Denmark, i.e. from ca. 5600 to 1700 cal B.C.

Bronze Age shell bearing sites (1700- 500 cal B.C.)

Marine shellfish was also collected during Bronze Age period, but on a much lesser scale than during the Stone Age. Small heaps or thin layers of marine shells are found in many settlements; however, we do not have any shell middens *senso strictu* (Nielsen and Simonsen 1996: 72, 75). The sites with marine molluscs are mainly coastally located, but molluscs are also found in settlements located up to several hundred meters from the prehistoric (Bronze Age) coastline, e.g. Vadgård (Rasmussen 1983) and Torslev (Johansen 1985: 118). In sum, it is obvious that marine shellfish were also exploited in the Bronze Age, but this activity was on a much smaller scale than during the Stone Age.

Iron and Viking Age shell middens (500 cal B.C. - cal A.D. 1050).

From the Early Iron Age kitchen middens reappear in large numbers and document a renewed and specialized activity on the Danish coasts compared to the Bronze Age (Figure 7). The majority of these sites date from ca. 500 cal B.C. to cal A.D. 400, but some are even younger and date from the Viking Age (ca. cal A.D. 775/800-1066). Besides the coastal middens, marine molluscs are also found frequently on the inland settlements, either as small heaps or restricted layers ranging in area from a handful of shells to a layer of ca. 49 m^2, and with a content of several cubic meters. It is the same species and in the

Figure 8. The distribution of Iron Age kitchen middens along the Danish – North German coasts (thick black lines) and inland settlements with smaller heaps of marine molluscs.

same relative number on the inland settlements as on the costal middens. Settlements with such shell deposits are especially numerous in North and East Jutland and are found in a restricted zone of ca. 1-6 km from the coast, indicating the width of a contact zone between the inland and the coast (Figure 8). We also have a small number of shell middens from the Viking Age period.

Form and size

In contrast to middens around the world, the Danish Stone Age shell middens are oblong and follow the prehistoric coastline (Figures 9 and 10). The form of the middens is a function of depositional and post-depositional processes. Series of ^{14}C-dating demonstrate that the shape and size of the middens is a function of the duration of occupation at the same location, and the dates reflect a gradual, chronological movement, both in a horizontal and a vertical way along the prehistoric coast, thereby creating the characteristic form. In cases where the shape and contour of the midden is well preserved, it can clearly be seen that they consist of more or less delimited heaps or small piles (Figure 10).

The oldest middens are small (10 x 20 m) and with thin shell layers (ca. 0.10 - 0.15 m) but, later on, during the Atlantic period, they expand rapidly in size and become larger with a length of 10 - 700 m, a width of 3-40 m and with a thickness of 0.10 - 1.8 m. Therefore, their cubic content varies from 2 to 5000 m^3. The majority of the largest Stone Age middens belong to the Ertebølle Culture, e.g. Ertebølle (Madsen et al. 1900) and Meilgaard (Madsen 1888; Andersen 1961). Nevertheless, some Early Neolithic middens are also very extensive, e.g. Visborg, with a length of ca. 600-700 m and a cubic content up to ca. 4000 m^3 , and Krabbesholm II with a volume of ca. 5000 m^3 (Andersen 2005).

The shell middens in Jutland (western part of Denmark) are generally more extensive with thicker deposits than the middens in eastern Denmark and, at the same time,

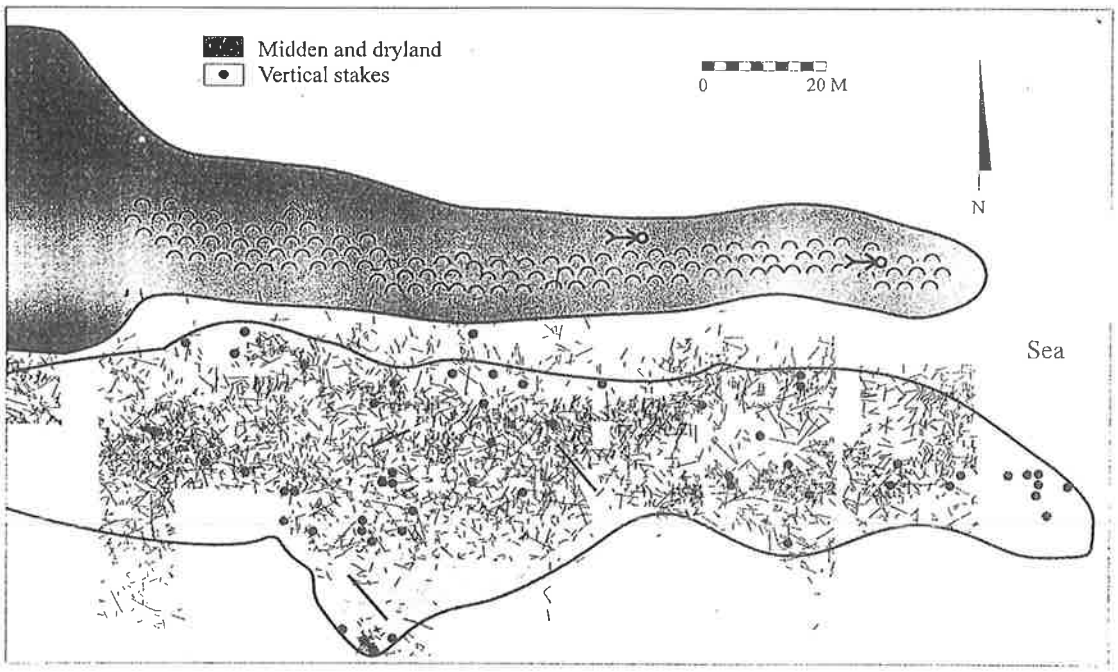


Figure 9. A simplified plan of the lay – out of the Lystrup shell midden in Eastern Jutland which belongs to the oldest Danish *Køkkenmøddinger*, ca. 5300 cal. B.C. On dry land we have the houses, some burials, and the midden, in which is oblong in outline and follows the coastline. In the shallow waters in front of the habitation, there is a mixture of outcast, waste zone and a fishing area with thousands of hazel stakes from destroyed fishing installations, e. g. fish weirs etc. J. Kaae.

the layers in the east Danish middens seem to be much more compressed, while the shells are thinner and smaller than in the Jutland middens.

The Iron Age *Køkkenmøddinger* are circular or oblong in outline and measure ca. 4 - 30 m in width, up to ca. 2-500 m in length, and have a thickness of ca. 1 m. In some areas, e.g. along Norsminde Fjord and Mariager Fjord in Eastern Jutland, the middens stretch up to 1 km in length with short interruptions. Their cubic content is therefore very large – up to 15,000 m^3, i.e. several times larger than the largest Stone Age middens (Figure 11a+b).

Types of *Køkkenmøddinger*

So far, it has not been possible to "rank" the Danish middens basing on types of accumulation, artefact intensity and inventory, features, settlement size, and topographic position. The largest group of shell middens is interpreted as a result of the year-round home base occupation, and characterised by a wide range of artefact types, while smaller sites exhibit clear seasonality, a more restricted artefact inventory and fewer features. Another group of shell middens is characterised by the presence of thick layers of shells without much cultural debris; this is a general aspect of Neolithic and Iron Age middens. Such middens seem to have functioned as pure "shell dumps".

Finally, there is a group of middens characterised by thin scatters of oyster shells without, or with very few, cultural remains associated. Such sites are best interpreted as ad hoc locations on the beach for consumption of shellfish (Meehan 1982: 112 - 118). An especially important type of *Køkkenmøddinger* in Denmark is the "stratified midden" or "Mesolithic-Neolithic midden", i.e. middens with series of horizons covering both the Late Mesolithic Ertebølle and Early Neolithic Funnel Beaker cultures that mark the transition from a hunting-gathering to a farming economy. Such settlements represent up to 1000-1500 years of topographic continuity on the same spot and, thereby, also demonstrate resource stability in the coastal region and subsistence continuity during this long time interval. In investigated regions, up to 80% of all the coastal settlements are such "stratified sites" and this type of coastal settlement seems to be the norm rather than the exception.

The ethnographic literature provides descriptions of several different types of middens, e.g. sites used specifically for the preparation and consumption of shellfish (daytime camps), e.g. processing sites, snack sites and meal camps, often located on the intertidal flats or beaches and settlements (overnight camps), used for one or several nights, weeks or months; there are many subtypes of both daytime and overnight camps (Meehan 1982, 1988). In the former case, the divisions are related to the activities which took place, whereas in the latter case it is the layout with regard structures, which define the individual types.

Composition

The Mesolithic shell middens are dominated by heterogeneous layers composed by a mixture of oysters (*Ostrea ed.*), cockles (*Cerastoderma ed.*), mussels

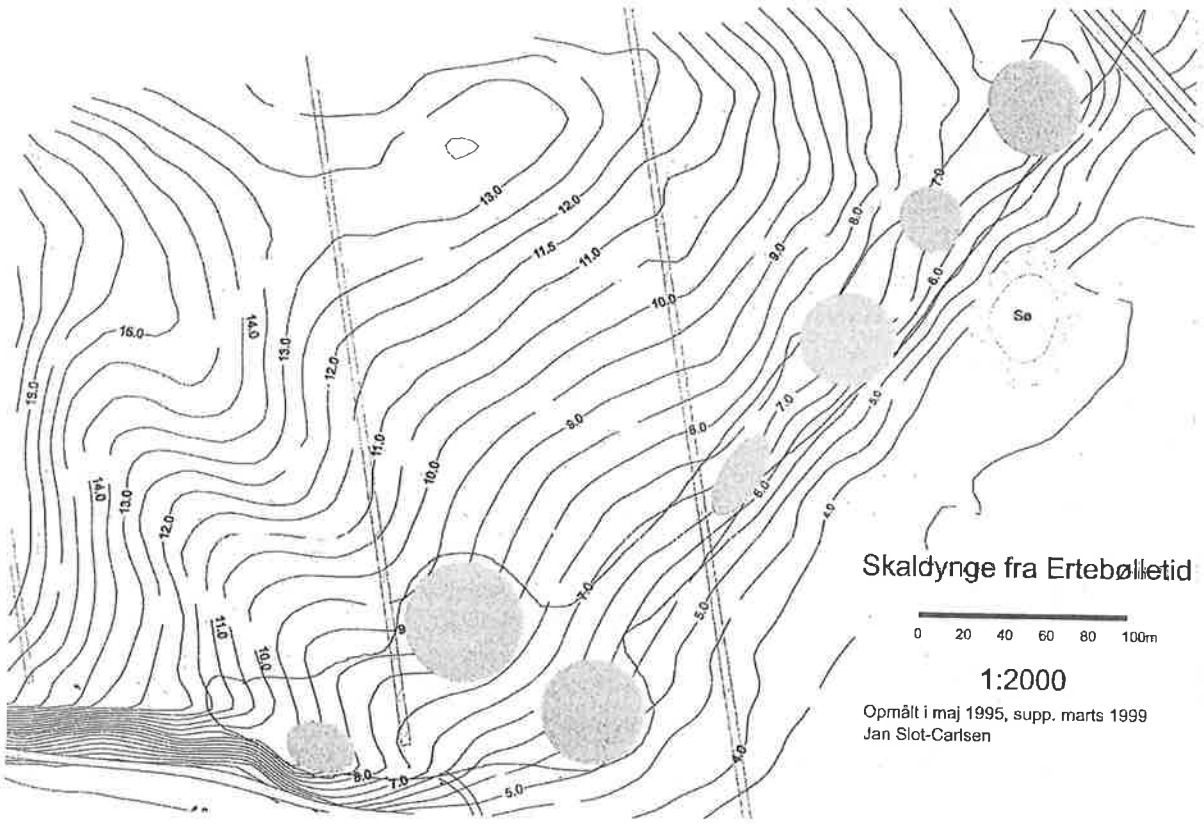


Figure 10. Plan of the Visborg shell midden from the Late Mesolithic and Early Neolithic (light shaded). The surface contour shows at least seven more pronounced heaps with thicker shell layers indicating more prolonged and intense occupation at these locations (darker shading). ^{14}C datings demonstrate that this midden mainly has accumulated in a horizontal direction and to a minor degree in a vertical way. J. Carlsen.

(*Mytilus ed.*), and periwinkles (*Littorina littorea*) (Figure 7). The oyster is always dominating in the Mesolithic kitchen middens and constitutes up to 50-90 % of all the marine molluscs, while the cockles make up 30-40 %, the mussels 10 %, and periwinkles 3-5 % (Figures 7 and 13). The matrix of the midden is mixed with a varying amount of sand, gravel, flint debris, flint and bone/antler tools, animal bones (especially fish bones), charcoal, potboilers, ceramics (only in the younger middens), hearths and a few burials. Sometimes, the horizons are dominated by one mollusc species only, and such layers are interpreted as "meal heaps" (Madsen et al. 1900: 25-28). The content of cultural debris is generally high in the Mesolithic middens. It is lower in the Neolithic, where some sites are nearly without any cultural debris. Due to the fact that many of the kitchen middens have been located close to the water´s edge, varying amounts of "natural" molluscs have been incorporated in the sediments, as exemplified by the deepest layers in the Ertebølle midden.

In most cases, the greatest number of finds is in the upper and lower layers of the midden. When the rhythm of accumulation has been broken, and the surface exposed for a longer time, or when the process of accumulation has been slow, the midden will be characterised by a crushed and compact mass of shells due to erosion and human traffic, and there will be a notably higher concentration of cultural debris and features.

By careful excavation it is possible to divide up the large sites in a series of individual, occupational episodes, thereby demonstrating that the larger ones in most cases consist of more-or-less clearly delimited, smaller individual depositions, e.g. Ertebølle (Andersen and Johansen 1986), with at least 50 different horizons in a 1 m wide section, and Krabbesholm with ca. 30 layers (Andersen 2005). The smallest, well-defined unit of debris seems to be ca. 3-7 m in diameter, corresponding in size with the smallest discrete middens and the smallest non-molluscan coastal sites.

At ca. 3950 cal B.C. there is an abrupt and synchronous change in the midden composition all over Denmark from dominance of oysters towards a dominance of cockles (Figure 14). The composition of the Early Neolithic Norsminde midden is 10 % of oysters, 70 % of cockles, 18 % of mussels and 2 % of periwinkles. This is the general feature observed in most Danish shell middens, e.g. Norsminde (Andersen 1991: 38). However, we also have a few sites, where the oysters continue to dominate into the beginning of the Neolithic, e.g. Visborg and Krabbesholm II (Andersen 2005). The last mentioned sites are characterised by a location with good access to more open seas with favourable salinity, which might explain the presence of oysters in the Early Neolithic at such sites. At the transition from the Mesolithic to the Neolithic there is also a change in the composition of the

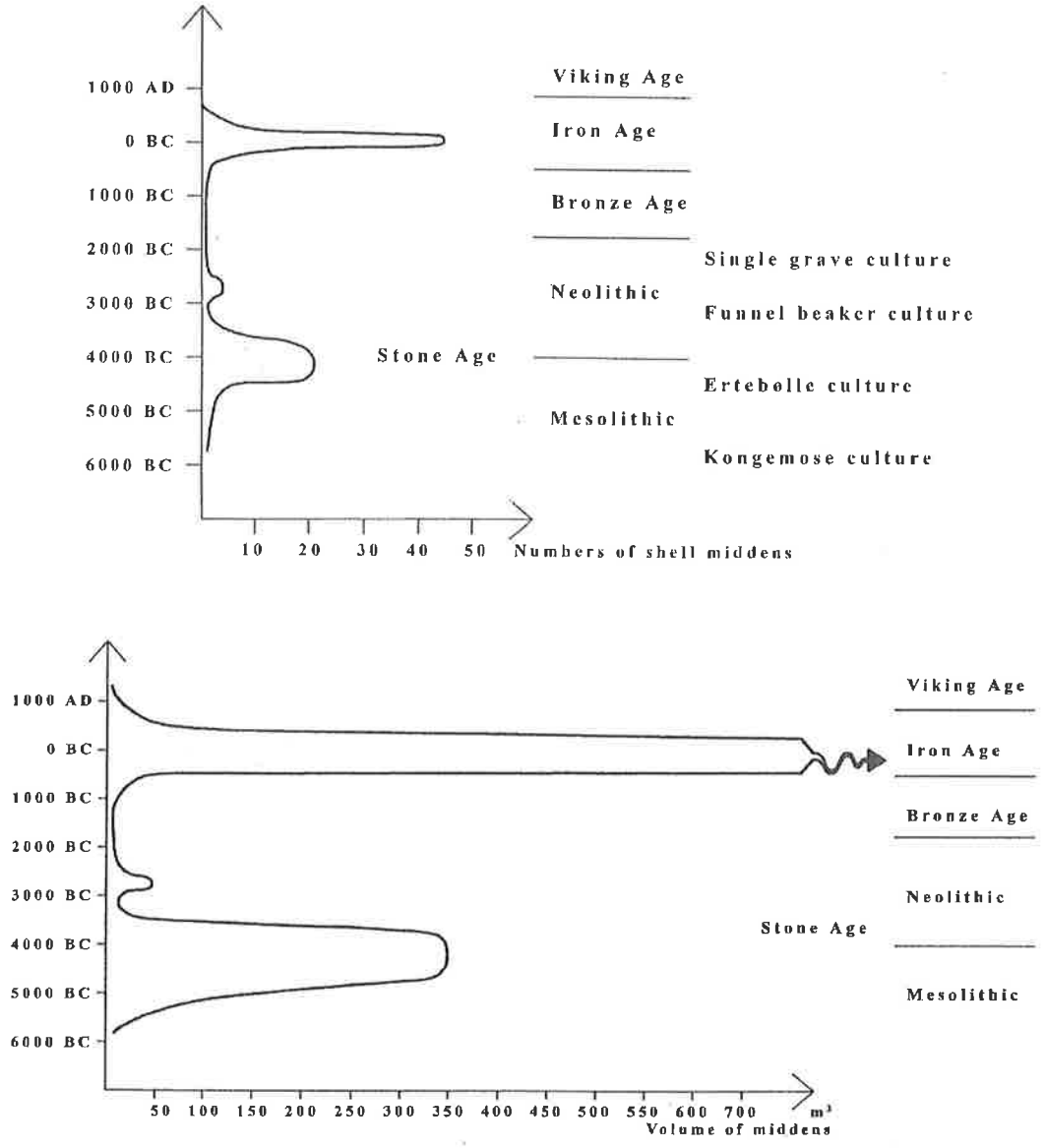


Figure 11. A) Number of shell middens along the coast of Norsminde Fjord as a function of time. B) Volume of the shell matrix from all shell middens along the coast of the Norsminde Fjord as a function of time. The plot shows that intensity of collecting marine molluscs increases strongly from the beginning of the early Iron Age. Cille Krause.

middens towards more soil and horizons of ash and charcoal with many potboilers. All these observations obviously indicate new types of activities in connection with the kitchen middens compared to the Mesolithic.

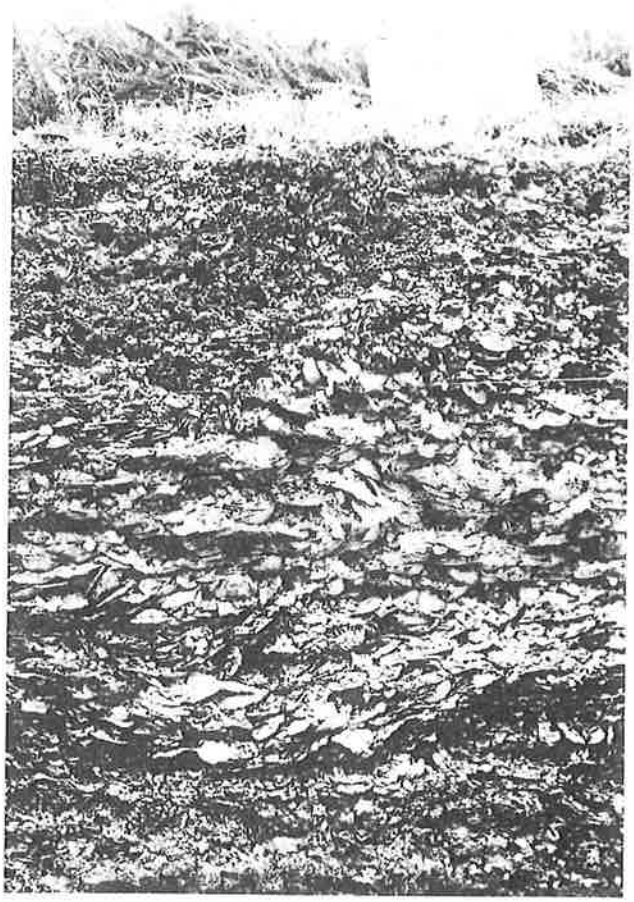
In the Middle Neolithic it is again (large) oysters, which dominate the middens, while the Late Neolithic middens are characterized by cockles. The mollusc composition of the Kalvø midden is as follows: 70 % oysters, 6,5 % of cockles, 20 % of mussels and 3,5 % of periwinkles (Andersen 1983: 71) (Figure 7).

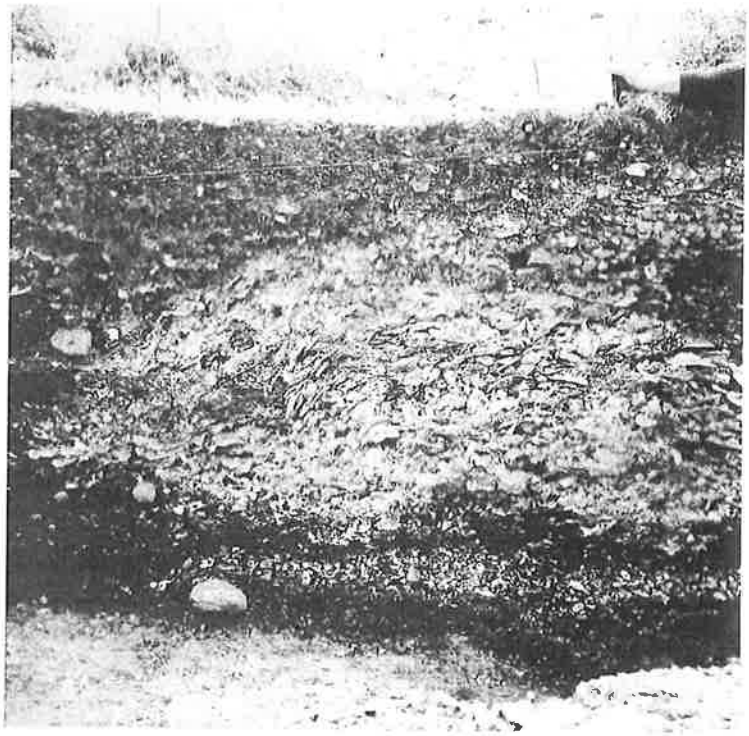
In the Bronze Age it is the mussel (*Mytilus* sp.), which is the dominant marine species in the assemblages. The oyster is also present in the majority of the sites, but always in very small numbers.

However, no quantitative or qualitative calculations of the mollusc content on Bronze Age sites have been published.

The Iron Age *Køkkenmøddinger* are generally dominated by mussels, but in a few cases cockle is the dominating species. However, periwinkles and small oysters are also recorded. An analysis of the Iron Age midden Store Nor II in Eastern Jutland gave a mollusc content of 62% mussels, 19% cockle, 11% of periwinkles and 9% oyster (unpublished Museum Report, FHM. j. nr. 2712) (Figures 7 and 15). The marine molluscs from these middens point to-wards a more salty sea with a slightly richer marine fauna than today (Anger 1974: 56–57; Petersen 1985: 24).

a)





b)

Figure 12. A and B. Sections through the Late Mesolithic Ertebølle kitchen midden (*locus classicus*). The dominant species is the oyster (*Ostrea edulis*). An essential part of the matrix is made up by food remains (mainly millions of fish bones) and other types of cultural debris, such as charcoal, animal bones, artifacts, ceramics and flint debris. Jan Petersen photos.

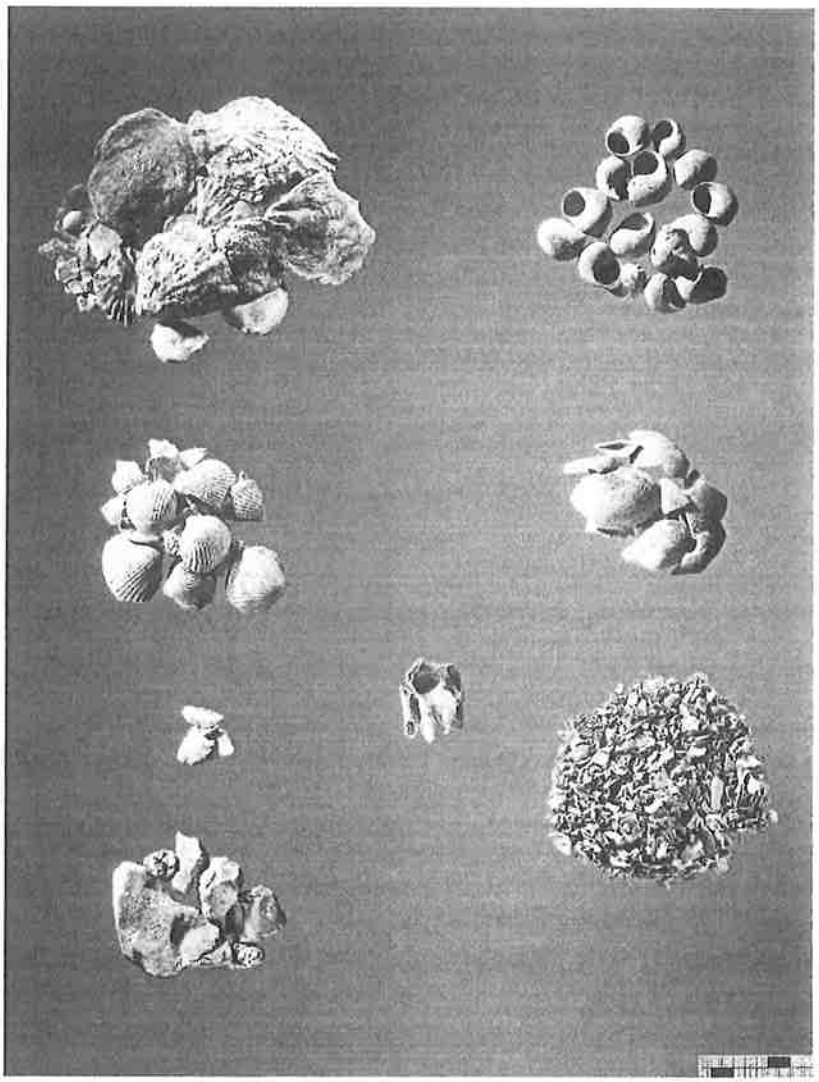


Figure 13. The different species from a Danish Mesolithic shell midden. Moesgård photo lab. **Top left:** Oysters and right: Periwinkles. **Mid. left:** Cockles and right: Carpet mussel **Bottom left:** Mussels. Mammal bones. Right: Fish bone. **Bottom left.** Small stones brought into the middens – probably attached to sea weed.

Usually, Iron Age middens contain only shells, charcoal and potboilers, while other cultural debris, e.g. animal bones and pottery are less frequent; this is a clear contrast to the shell middens from earlier prehistoric periods (c.f. Figures 13 and 15). Just like the Stone Age middens, these are also made up of series of individual horizons resulting from individual activity episodes. The number of potboilers is very large, and they are frequently found in circular concentrations, either "dumps" from cooking activities or hearths. No types of settlement features have been recorded from these middens (Poulsen 1979: 76-77; Harck 1974: 52).

The high content of charcoal and potboilers in the midden layers clearly reflects cooking and maybe also drying and smoking of mussels in this period (Poulsen 1977: 77). These activities are well known from the ethnographic literature (Noe-Nygaard 1967: 181). However, the frequent presence of shellfish in the inland settlements also demonstrates that the consumption/processing of this type of food was not only a coastal activity, but also took place far away from the coast. The size and cubic content of these middens demonstrate a comprehensive and intense gathering of mussels nearly on an "industrial scale", which must reflect a large social enterprise and organisation, not only in the gathering and processing the mussels, but also in the procurement of the large amounts of firewood needed for the cooking activities. This raises the question if these activities were geared towards local consumption or for a wider distribution?

The variation of species through time in the Danish shell middens is so characteristic and appears to be so generally valid that it can be used for making a rough dating of middens, even when datable artefacts are lacking.

Settlement features

The Mesolithic middens comprise many settlement structures, such as different types of hearths, pits, stake-

holes, fish bone layers, dwellings and a few graves of humans and dogs, which separate them from middens from other (later) prehistoric periods; these features are usually linked with the concept of the "settlement". However, only very few house structures have been found in association with the Danish kitchen middens (Sørensen 1995: 20-22, Figure 2). Some middens have an internal structure demonstrated by either the vertical position of fireplaces within delimited areas of the middens or by hearths systematically spaced along the prehistoric coastline. These phenomena most probably reflect a social organisation of the settlement. Within the large middens we can also discern areas used for food production and "discard-areas" for shellfish; it has been demonstrated, that the fireplaces clearly were "loci" of activities such as flint knapping and food processing (Andersen and Johansen 1987: 46-48).

The few structures recovered in the Neolithic middens indicate that they do not seem to be regular settlements, but rather represent "shell-dumps" on the beach, where cooking and some flint knapping took place. The potboilers are found in layers mixed with charcoal or in delimited piles, probably debris/dumps from hearths. New excavations show occupation horizons behind the middens, for instance at Norsminde and Bjørnsholm; an indication that the actual settlement has been located just behind the midden (Andersen 1991: 38; Andersen 1995: 65-66). Thus, we see a trend from "midden settlements" in the Mesolithic to more "specialised" sites for shellfish procurement in the Neolithic. The Iron Age middens are not settlements, but rather specialised coastal sites used for gathering and processing of mussels (Harck 1974: 54; Poulsen 1979: 77-78).

Seasonality

Seasonality studies of the Stone Age middens have been carried out on faunal remains, marine molluscs (especially oysters) and fish otoliths. The analyses reflect activities carried out during several different seasons on the larger sites, while the smaller ones more often show a seasonal occupation. Fowling for swans was an autumn activity as demonstrated at the Aggersund (Andersen 1979; Møhl 1979: 57-75) and Ertebølle sites (different species of ducks and swans), while hunting for furred animals was a winter activity (Madsen et al. 1900: 81-89).

The gathering of oysters during the Mesolithic times took place during March and April, while this activity continued into the summer months of June, July and August during the Neolithic (Milner 2002: 90); fishing was a summer activity (Enghoff 1994: 89). The terrestrial fauna elements indicate both summer and winter activities (Madsen et al. 1900: 175). The larger sites have been visited several times during the annual cycle, but we *still* lack evidence of permanent and continuous whole year occupation.

Analysis of shells from North German Iron Age middens show that they are seasonal sites used in the late summer or autumn (Anger 1974: 59). It is reasonable to assume that a similar seasonal pattern has been the case for the Danish Iron Age middens.

Investigations around and beneath the Danish shell middens

In order to cast new light on the essential question as to where the occupants actually lived during midden accumulation, extensive excavations have been performed in the areas beneath, around, and in the shell middens. The area beneath the *Køkkenmøddinger* is generally rich in cultural remains indicating that substantial occupation took place before shell accumulation started (the so-called pre-midden occupation horizon); these occupation layers seldom contain shells. Such pre-midden layers have been ^{14}C dated to around 4600 cal B.C. and represent a type of settlement clearly different from the kitchen middens. Such horizons demonstrate that, at about this time, there was a change in the scale and significance of collecting marine molluscs, and this resulted in the beginnings and rapid accumulation of many of the largest Danish *Køkkenmøddinger*.

On the seaward side, "in front" of the middens, we often find a "drop-zone" consisting of layers of debris thrown and washed out into the sea and embedded in the marine sediments. By degrees, a fair number of excavations have been undertaken of the area "behind" (i.e. on the landward side) of the shell middens. These investigations have demonstrated thin cultural layers and structures contemporary with the midden in this area, but we still have not been able to establish whether the dwellings in some cases were situated behind the *Køkkenmødding*.

Taken as a whole, there has been habitation before (below) the shell midden began to accumulate, and in the area immediately behind the middens, as well as on the midden, during the accumulation of the *Køkkenmøddinger*. The preliminary conclusion is that the dwellings were on top of, or dug into, a shellfish pile, and that the population actually lived upon the shell heaps.

Marine exploitation

The location of the Mesolithic shell middens at good "fishing-localities", the tool types (hooks, fish weirs, leisters, nets and dug-out canoes up to ca. 9-10 m long), bones of fish, seals and whales, the results of the analysis of charred food remains with fish bones and the content of ^{13}C in human and dog bones, prove that the sea and its resources was essential for the Late Mesolithic population. Add to this a specialised hunting implement as the harpoon, which appears in the Ertebølle Culture in different subtypes (Andersen 1997: 45-99) (Figure 16).

The importance of the marine biotope for the Late Mesolithic population is also attested by finds of marine indicators on inland settlements such as Ringkloster in Eastern Jutland (Andersen 1975: 88-89; 1998: 46-47, 54) and in the Åmosen on Zealand (Noe-Nygaard 1971: 25). We can clearly use the term "coastal fishermen" for the

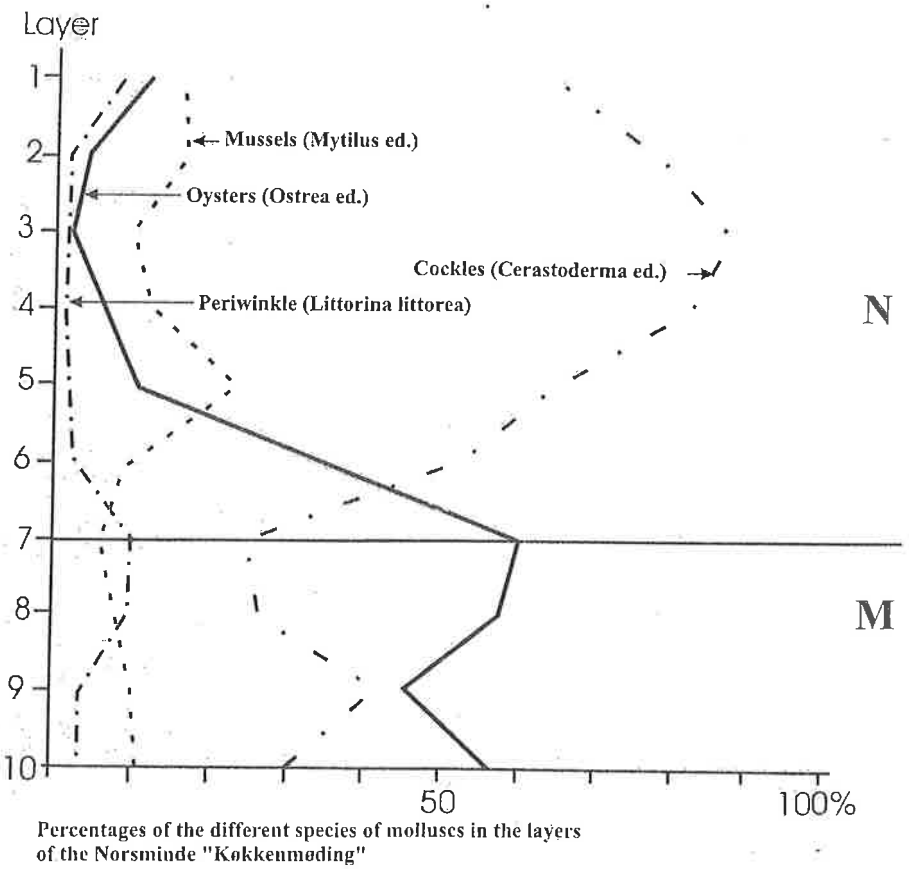


Figure 14. Graph of the dominant marine species through the Mesolithic and Neolithic midden sequence at Norsminde. The whole stratum covers the time span from 4600 – 2500 cal. B.C. Observe that variation in the oyster frequency, which shows a clear decrease from the Mesolithic to the Neolithic and a later increase in frequency in the top layers 1, 2 and 3 (Early middle Neolithic), cf. Figure 7. After G. N. Bailey.

population living during the main part of the Danish Late Mesolithic. However, shell middens were not the only type of coastal settlement during the Ertebølle period; they are found along the coasts interspersed between non-molluscan sites (so called ordinary coastal settlements). Therefore, shell middens cannot be regarded in isolation, and their location follows the general settlement patterns of the Ertebølle culture. As one of the most essential factors regarding the location of the coastal settlements was the access to good and stable fishing grounds. It is evident that this economic aspect was also one of, if not, the main parameter(s) for this type of site. Mesolithic fishing seems to have been a seasonal (summer) inshore activity by means of fish traps.

The Danish Ertebølle coastal population demonstrates technological complexity and probably also cooperation in resource exploitation, because sea-mammal hunting requires a complex technology and cooperation among hunters, e.g. a certain degree of boat crew specialization. The location of the coastal sites at the good fishing locations and the content of the cultural horizons indicate that the marine resources also played an essential role in the Early Neolithic economy. Despite the gradual introduction of a farming economy, the majority of the Early Neolithic settlements are coastally located and very often at the same spots as the Mesolithic ones. The exploitation of the marine biotope during the Early Neolithic is well documented by many shell middens along the coastline, not only by bones from fishes and seals, but also by fish hooks, evidence of manufacturing of harpoons and several fish-traps and fish fences (Pedersen 1997: 142, Figure 23). Fishing during the Early Neolithic was mainly a summer activity, and with the same species and in relative numbers as in the Late Mesolithic, e.g. Norsminde site (Enghoff 1994: 117). Shellfish gathering and sea mammal hunting (seals and small whales) again became of importance in the Middle-Neolithic, ca. 2800 cal B.C. This period shows a quantitative increase in coastal settlement sites with shell middens and is also characterised by several finds of harpoons and new types of flint points for hunting. From the Neolithic, we also see a special type of (small) coastal settlement, which mainly has been used for seal hunting during several millennia and, thereby, reflects a similar long tradition of marine hunting at specific locations along the coasts, for example at Selbjerg (Marseen 1953) and Rønbjerg Strandvolde sites (Skousen 1998).

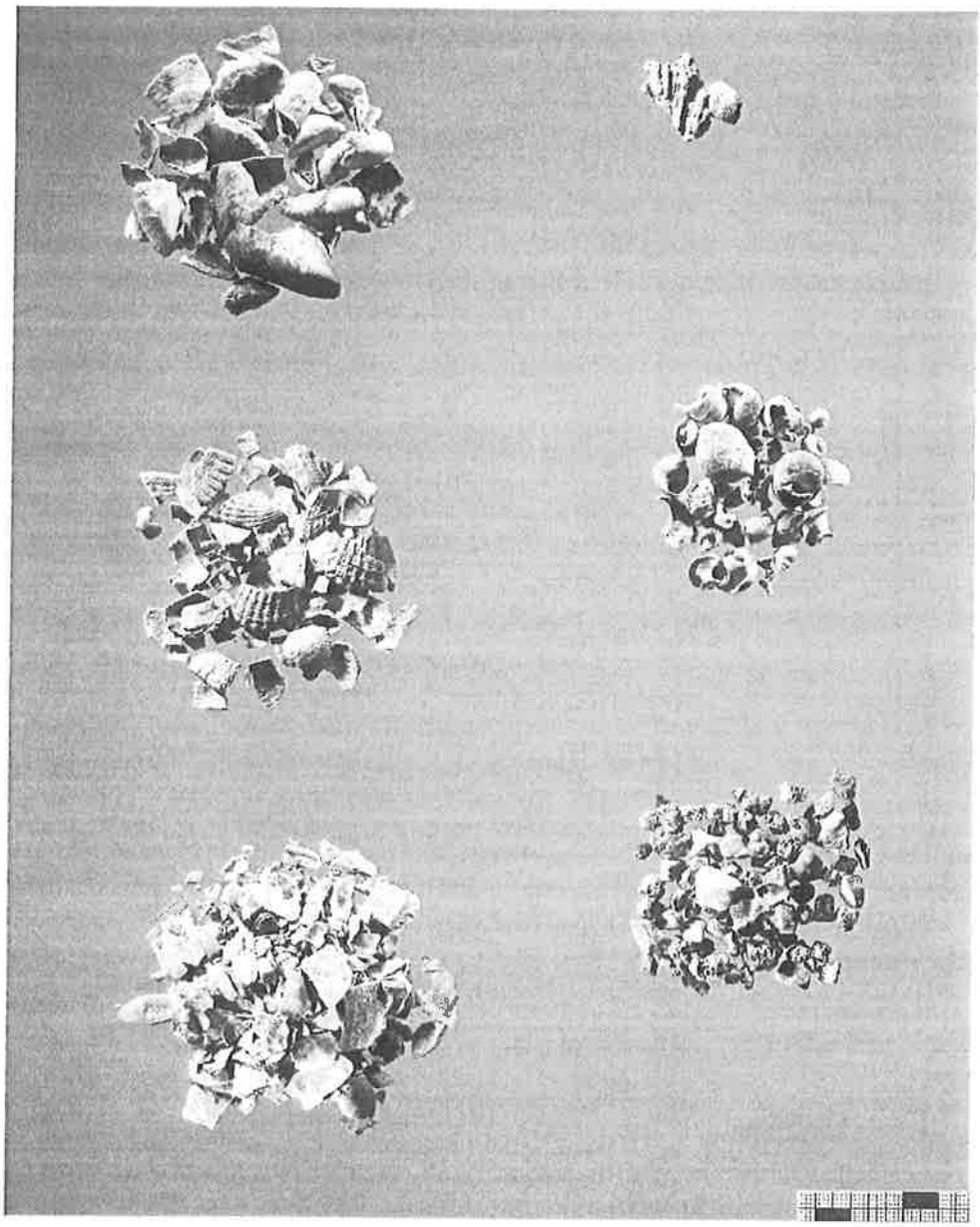


Figure 15. The dominant marine molluscs from an Early Iron Age shell midden. Top row Left: Mussels. Right: Oysters. Mid row Left: Cockles. Right: Periwinkles. Bottom row Left: Crushed mussels. Right: Gravel from crushed "pot-boilers." Moesgård photo lab.

From the Neolithic and onwards through the rest of the Danish prehistory, we see a new type of economy in the coastal zone, a mixture of a fishing and farming economy and, from there on, we can talk of "fisher-farmers", an economy which can be traced up to modern times in Denmark. While the Mesolithic and Early Neolithic middens are always lying on the prehistoric shorelines, the Middle Neolithic shell bearing sites are sometimes found at a distance from the sea, ca. 0.2-2 km from the coastline, for example Signalbakken site in the Limfjord (Madsen et al. 1900: 147-163). These figures indicate that the zone along the sea, which had an economic importance for the population, was broadened through the Stone Age from a very narrow line along the beaches in the Mesolithic to a wider zone of up to several kilometres during the Neolithic. These observations indicate a change of the settlement pattern from a linear to a planar one (Yesner 1999: 729).

There are no traces of large scale exploitation of the marine biotope during the Bronze Age. It is possibly a function of few excavations of coastal sites and few settlements with good conditions for preservation of organic material. However, the coastal location of many settlements, the fish bones (representing up to 15 different species), shellfish and fishhooks of bronze and stone net sinkers, all together show that fishing and collecting of marine molluscs still played a role in the subsistence, at least in the coastal zone. Add to this also the occasional use of sea weed and beach gravel in

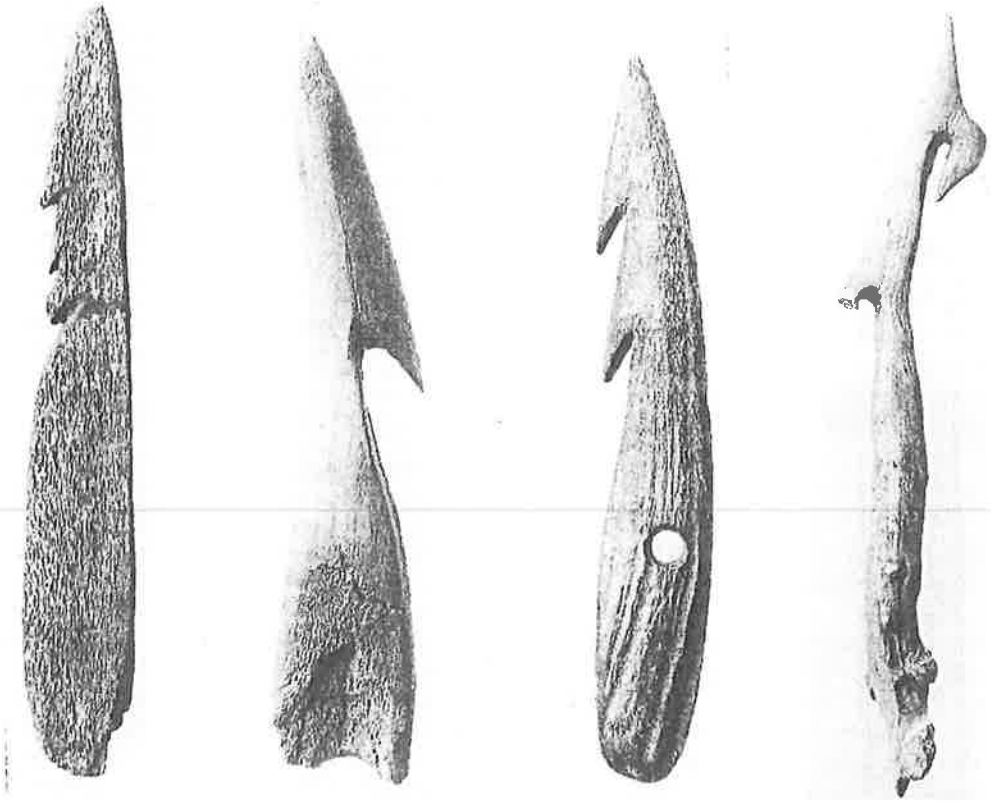


Figure 16. The main harpoon types of the Ertebølle culture, ca. 5400 – 4000 cal. B. C.
From left to right: The first harpoon is made of whale bone, the next two from red deer antler, and the last (far right) from roe deer antler. Scale 1:2, Moesgård photo lab.

burials (Aner and Kersten 1977: 232). Analyses of fish bones show that the sizes of the fishes are larger than earlier, indicating that this subsistence activity was now concentrated on large individuals of cod (*Gadus morhua*) caught on the open sea (line and hook fishing).

Bones of different species of seals and whales are also present in the settlements (Berntsson 2005). Other indications of exploitation of the marine biotope are the recovery of a stranded? finback (*Balaenoptera physalus*) at Vængesø in Eastern Jutland dating from the Bronze Age, 1210-970 cal B.C. and, on a nearby coastal settlement, there is a culture layer with a concentration of fish and whale bones, most probably the remains of a specialised "whaling-site" (Andersen 1975b).

In the Limfjord area in Northern Jutland, very rich burials in the beach ridges indicate habitation on the coast and exploitation of the marine resources, for example at the Hverrehus (Broholm 1940) and Mellemholm sites (Grantzau et al. 1953). The richness of these graves demonstrates that the coastal habitat formed a solid economic basis for the local Bronze Age population. Finally, it is also worth mentioning that analyses of the ^{13}C content in human bones from this period showed that half of the investigated persons had consumed a significant amount of marine food (Berntsson 2005: 120).

Although there are still very few finds of fishing equipment from the Iron Age period (hooks and leisters of iron, stone net-sinkers and bone points), the thousands of fish bones on many settlements, especially in Northern Jutland, demonstrate that we still have a fisher-farmers economy as during the previous periods, at least in the coastal zone. The main fish species in Northern Jutland is flounder (*Platichthys flesus*) which, at some settlements, makes up to 68 % of all fishes, while the herring (*Clupea harengus*) dominates in Eastern Denmark. Fishing during this period seems to have been a local, coastal and summer activity, and net fishing has been widely used (Enghoff 1992, 1999: 52 – 53).

Scattered bones of killer whale (*Orcinus orca*), common seal (*Phoca vitulina*), grey seal (*Halichoerus grypus*), and porpoise (*Phocaena phocaena*) are known from several coastal sites (Müller 1906; Møhl 1971). Along the Northern coast of the island of Funen, and in Eastern Jutland, we have many scattered finds of simple bone points, and it is reasonable to assume that they have been used as equipment for sea mammal hunting, especially seal (Henriksen 1997). In conclusion, we know that the Iron Age population also used the marine biotope for gathering of molluscs, fishing, and for the hunting of seals and whales. These economic activities seem to have been of special importance along the coasts and in a coastal zone of 1-6 km from the shores.

Later on, during the Viking Age (cal A.D. 775/800-1050), we still find clear indications of fishing demonstrated by isotopic analysis of human bones from the coastal zone, for example in the Aggersborg site (Tauber 1981: 125), and the appearance of a new fishing tool, the leister of iron used for catching flat fish (Figure 17). There is no reason not to assume that fishing also must have been of importance in the Viking Age economy, at least in the coastal zone.

In spite of the overwhelming impression made by the sight of the millions of mollusc shells in the shell middens, it is unlikely that shellfish were of primary nutritional importance; they were rather a dietary supplement. Calculations have been made on several occasions of the food value which mollusc shells in middens represent, and there is every indication that shellfish were only an addition to the stable diet, but not food enough to be a principal source of nourishment for the population. The suggestion has been put forward that the importance of shellfish is more likely to have been the nutritional value of their salts and minerals, such as iodine and zinc, rather than as a staple food (Møhl 1979: 66 – 67).

Variations in the number, size and mollusc content of the Danish *Køkkenmøddinger*

During the prehistory of Denmark we observe a series of changes in taxonomic diversity, the number of shell middens, their size, the content, and the dominant shell species and in the cubic volume. The oldest middens are all characterized by a dominance of oysters. A shift from oysters to cockles took place ca. 3950 cal B.C. In the following Neolithic periods there is a decrease in the number and size of the kitchen middens, but when they reappear, ca. 2800-2500 cal B.C., they are again dominated by oysters. In the Late Neolithic, ca. 2300-1700 cal B.C., it is the cockle which dominates the shell deposits on the settlements, for example in the Myrhøj site (Jensen 1973). There are no shell middens from the Bronze Age, only small piles of mussels. From the Early Iron Age we see a new increase in the number and volume of shell middens, which now are dominated by mussels, through the remaining centuries of the Danish prehistory and early history.

The explanation for the variation in the composition of the middens could be due to environmental changes in the topography and/or in the marine biotope, primarily changes in the temperature or salinity of the sea, but also sea level, sedimentation rate and change in the area of intertidal flats have to be taken into account. Besides that we cannot forget to incorporate environmental changes in the larger seas around Denmark, especially the English Channel and the North Sea. Topographic alterations in these areas must have had a great impact on currents and tidal ranges in the Danish waters. However, cultural preferences should not be completely ruled out. If we try to understand these variations in the kitchen middens and their content of marine species, as well as in the number of contemporary costal settlements, it is obvious to compare the *Køkkenmøddinger* with the natural shell banks. A comparison of the number of shell middens with the coastal settlements *in toto* reflects a striking correlation in the fluctuations and frequency of natural shell banks. This is clearly an argument against "cultural factors" as an explanation for the variations. Another fact is that these changes seem to be relatively "fast" (i.e. within one standard deviation) and synchronous over the whole Danish region.

The sudden occurrence of the Danish shell middens at ca. 5600 cal B.C. corresponds with a rise in the salinity, the temperature and the level of the Atlantic sea at this time, which probably also explains the appearance and growth of oyster banks in the Danish waters. At ca. 4000 cal B.C., there is a significant change in most Danish middens from a dominance of oysters towards a dominance of cockles. The explanation for this change in species is most probably to be found in environmental alteration of the marine biotope. At this time, there is also a decrease in the salinity and mean temperature of the sea. The new geological investigations point towards a lowering of the tidal range, which resulted in a fast increase in the sedimentation (silting) of many Danish fjords (Pedersen and Petersen 1997: 73, 81-82). The change from cockles to mussels in the shell deposits of the Early Bronze Age could also best be explained as a reflection of another change in the marine environment. At two natural shell banks a similar shift from oysters/cockles to mussels is ^{14}C-dated to the period ca. 1880-1620 cal B.C., for example in Tastum Sø in Northern Jutland (Rasmussen and Petersen 1980), and to 1600-1465 cal B.C. in Roskilde Fjord. The almost complete disappearance of the oyster most probably reflects a decrease in the temperature and salinity of the sea. The explanation for the reappearance of shell middens dominated by mussels in the Early Iron Age is most probably also to be found within the environment; the presence of some oysters in these middens points towards an increase in salinity and temperature in the sea.

What was the "role" of middens in the different periods?

In the Danish Stone Age the marine molluscs have nearly only been used as a food resource; in a few cases the shells have been used as scrapers, e.g. on the inland settlement Ringkloster (Andersen 1998: 46-47, Figure 34), and as raw material for the production of small circular beads. Ethnographical studies give some clues as to some of the roles of shell middens in prehistoric societies. From northern Australia it is documented that middens that have not been used in living memory could be attributed to ancestors or ancient heroes or animals. They are thus special, meaningful places in the landscape after their practical use has ended. Those middens in use as overnight or daytime camps are perceived as planned and patterned living spaces. This also seems to hold true for archaeological sites and shows the need to consider the possibility that all shell middens are deliberate "constructions" rather than random heaps of shell refuse.

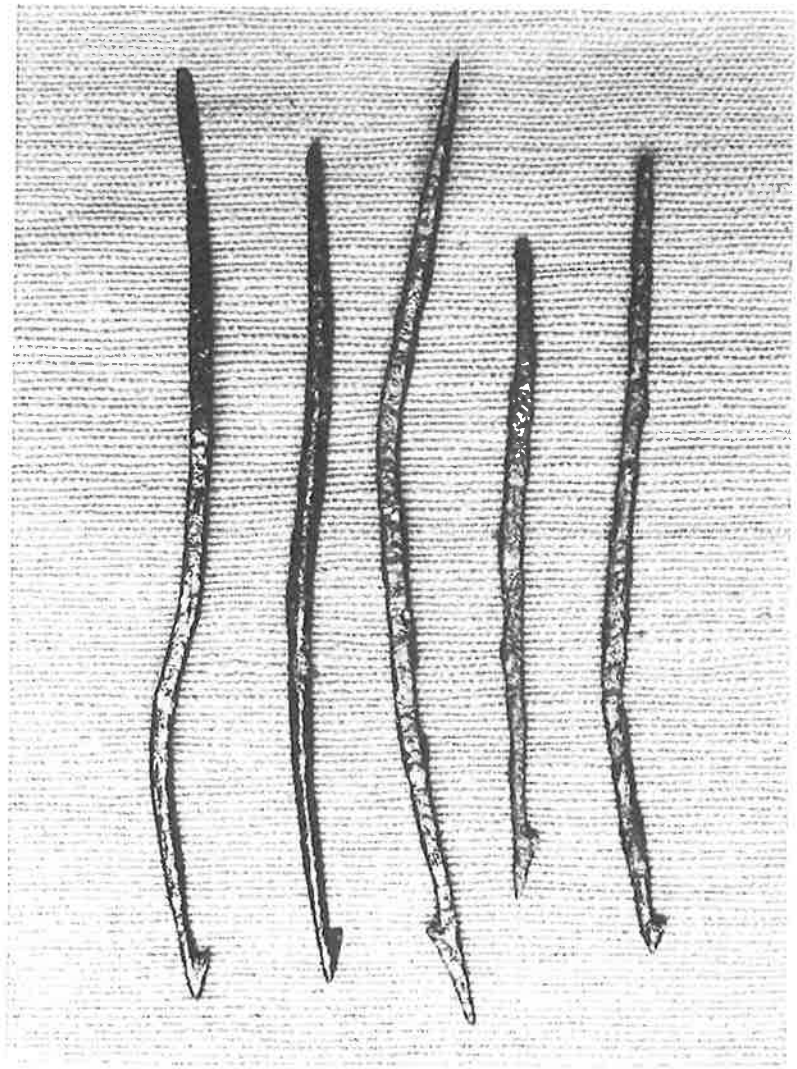


Figure 17. Leister prongs of iron from the Late Iron Age /Viking age settlement Sebbersund in Northern Jutland. Jan Carlsen photo.

From this also follows the possibility that the middens could have functioned as territorial markers along the coastlines. In the Danish environment, in the Atlantic and densely forested environment, such middens must have been lying along the coast as grey-white heaps or chalk cliffs without vegetation and must, therefore, have been visible from far away.

In several of the large Mesolithic shell middens in Denmark, e.g. in Bjørnsholm (Andersen 1993) and Norsminde (Andersen et al. forthcoming 2007), it is possible to document a gradual, but continuous decrease in the size of the oysters as a function of time. This change in shell size is most probably a reflection of human impact on the population, i.e. overexploitation. However, this observation is also interesting from another point of view as an indication that the group only exploited one (and the same) shell bank through the occupation period, and not shifting among several ones to compensate for the diminishing size. This observation might indicate a type of territoriality or "ownership" with regards to the use (exploitation) of the individual shell banks. A similar tribal control of shellfish banks is known from the Yahgan (Yesner 1980: 732).

Future research in Danish shell middens

From the last 25 years of research it is obvious that it is necessary to direct future excavations towards exposing large areas of the middens. It is the investigation of midden's surfaces or living floors, which yield the most promising and important data about the site layout. Besides, ethnographic comparisons must be used more frequently to provide a wider range of possibilities for the interpretation of the middens and such living floors. It is also essential to pursue the quest for well-defined dwelling structures. Here, it is necessary to concentrate on the fireplaces and the area around these because, very often, these are likely to indicate the presence of dwellings.

A series of questions has to be investigated in the future. What was the function of the shell middens in the total settlement pattern? How many different types of shell middens do we have? Did the shell middens have a

"special" social and/or economic importance? What was the internal social structuring of the *Køkkenmødding*? How much of the *Køkkenmødding* was in use at the same time? How and how often did people change living places on the shell heap? Further investigations and dating of "natural" shell banks are also necessary.

Finally, we also have to excavate modern, test-middens to investigate and measure the different taphonomic processes which have taken place since the prehistoric periods. In a forest, in the proximity of our institute, we have made a modern test midden which has now been lying for 16 years without any disturbance; this summer we are beginning to excavate a small part of it to obtain new insight in the formation processes of the Danish *Køkkenmøddinger*.

Today the Danish shell middens are heavily threatened by modern agriculture, plantations and construction works, and almost everywhere these distinctive ancient monuments are being ploughed up and destroyed. Comparisons between sections drawn in the 1890s and during recent investigations demonstrate that only about one-tenth of the original thickness of many shell middens is still relatively intact! Despite this depressing fact, only 19 middens (or sections of middens) are today protected by law. If we are still going to continue shell midden research in Denmark in the future, in one of the "classical" areas for this type of archaeology, then it is of prime importance to conserve as many scientifically important *Køkkenmøddinger* as soon as possible, in order to save the basal information from as many as possible. That is one of our main tasks for the future!

Conclusions

Denmark has 7000 years of history of shellfish exploitation. The marine biotope has always played an essential role in the Danish prehistoric economy, and this fact is explained by the geographical position of this country in Northern Europe, between the North Sea and the Baltic, and by the special Danish topography with an extremely long coastline and a mixed biotope between sea and land.

The oldest shell middens in Denmark date back to 5600 cal B.C. and, from then on, we can follow this cultural phenomenon until early historic time, ca. cal A.D. 1000. During this long time span, the archaeological record reflects several changes in the composition of the middens from a dominance of oyster in the Mesolithic, to cockle in the Neolithic and, finally, to the mussel during the Bronze and Iron Age. If we assume that the population behaved opportunistically, then the varying number and size of shell middens and coastal settlements and their species are a sort of measure for the varying productivity of the marine biotope.

If we compare a curve of the number of shell middens and the number of coastal sites as a function of time, with a curve of the variations in sea level and salinity, there is a surprising correlation, which could not be accidental. Whenever we have a rise in sea level (transgression) there is also an increase in the salinity and the number of oyster banks as well as the number of *Køkkenmøddinger*. Shell middens or coastal occupation in general seem to flourish in periods characterised by a rich marine biotope. Coastal habitation can, therefore, be seen as a direct reflection of these variations in the marine biotope. The oyster is more sensitive to changes in the salinity, temperature and sedimentation than the other molluscs. Hence, as a working hypothesis for future research I see the varying frequencies of the oyster as a reflection of the productivity of the prehistoric sea and, thereby, also as an explanation for the variations in the coastal habitation.

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