

Late Mesolithic-Early Neolithic Sealers: a case study on the exploitation of marine resources during the Mesolithic-Neolithic transition in the south-western Baltic Sea

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Cite this as: Glykou, A. (2014). Late Mesolithic-Early Neolithic Sealers: a case study on the exploitation of marine resources during the Mesolithic-Neolithic transition in the south-western Baltic Sea. 'Human Exploitation of Aquatic Landscapes' special issue (ed. Ricardo Fernandes and John Meadows), Internet Archaeology 37. <http://dx.doi.org/10.11141/ia.37.7>

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Keywords: Mesolithic, Neolithic, harp seals, grey seals, exploitation patterns, butchery, hunting

This issue has been funded by the Graduate School "Human Development in Landscapes", University of Kiel with additional funding from the Institute for Ecosystem Research, University of Kiel and the Centre for Baltic and Scandinavian Archaeology, Schloss Gottorf.

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Summary

This article explores the economic significance of marine resources in the south-western Baltic Sea during the transition to agriculture. Faunal remains are used in order to explain subsistence patterns, including preferred prey, exploitation of specific ecozones, hunting methods and techniques, butchering and dietary patterns. Seasonality can be linked to specific economic advantages that result from natural faunal abundances and not selective hunting. The importance of marine resources remains steady during the transition to agriculture, as shown by residue analysis on ceramic vessels from the same archaeological context as well as by faunal abundance.

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1. The Site

The [submerged site of Neustadt](#) is situated in the Lübeck bay of the southern Baltic Sea in Northern Germany and was excavated between 2000 and 2006 by S. Hartz of the Archäologisches Landesamt Schleswig-Holstein (Hartz [2004](#)). As a result of the rise in sea level over the last seven millennia, the site now lies 3 to 5m below sea level. The excavated area recovered a coastal dump of cultural debris, where the finds were deposited in a 0.20 to 0.50m deep mud layer beneath a thick sand layer, thus resulting in excellent preservation conditions (Hartz [2004](#)). The site represents use over some 600 years, according to a number of 14C dates that fall between 4400 and 3800 cal BC (Glykou [2011b](#)). Thus, the site of Neustadt covers the transition to the Neolithic, which occurred at the end of the 5th millennium BC (Hartz [2004](#); Hartz and Lübke [2006](#); Glykou [2011b](#)). A stratigraphic division into different phases was not possible during the excavations and subsequent spatial analysis of refitted ceramics and bones has not been able to reveal any further detail (Glykou [2011b](#)). According to palynological analysis (Hartz *et al.* [2011](#)) the area underwent several periods of alternating drought and flood owing to successive changes in sea level, which resulted in a restricted soil accumulation. At the same time, the refuse zone also appears to have served as an activity area e.g. for the setting up of fishing nets. Consequently, human activity in the area might have contributed to a compression of already thin culture layers. The bones have all been analysed together because of the lack of stratigraphy (Glykou [2011a](#); [2011b](#)).

2. Material and Methods

The faunal material consists of 12,693 bones recovered between 2000 and 2006 during the excavation of the submerged site. A total of 3847 bone fragments from mammals, birds and amphibians have been identified. Fish bones were determined from four selected sectors of the excavated area. The identification of mammal bone fragments and determination of species was carried out at the Archaeological State Museum Schloss-Gottorf in Northern Germany by using the vertebrate reference collection of the Archaeological-Zoological Working Group (AZA). Zoologists from the AZA analysed the material from the first two excavation years, while the bones from the excavation years 2003-2006 have been analysed by the author. The fish bone determination was carried out by specialists at the same institute.

The characteristic morphology of pinniped bones makes their identification in a faunal assemblage fairly easy. However, the distinction between different seal species, as in this case between harp, grey and ringed seals, is more difficult because all these species are morphologically very similar. Cranial bones can be distinguished with confidence but the use of postcranial bones for species identification can give varying results (Hodgetts [1999](#)). Thus, axial elements, such as vertebrae and ribs, cannot be used to distinguish between species, while lower limb bones are unreliable as species indicators (Hodgetts [1999](#)). Therefore, identification of pinniped bones at a species level occurred on selected skeletal elements that allow a secure determination (for descriptions of the criteria see Heinrich [1991a](#); Hodgetts [1999](#); Storå [2001b](#); Ukkonen [2002](#)). These were skull, mandible, scapula, humerus, radius, ulna, femur, tibia and fibula. All the remaining skeletal elements have been identified only to family level (Phocidae indet.).

Quantification of frequencies includes NISP (Number of Identified Specimens) and MNI (Minimal Number of Individuals) (Binford [1981](#); Lyman [2008](#)). In this study, to calculate the MNI, which is typically obtained by the higher number of left or right skeletal elements for one taxon, fragmentation of the bones, sex and dentition were taken into consideration.

Age estimation at the time of death was obtained by using epiphyseal fusion data. Ageing of pinnipeds according to fused/unfused epiphyses allows a rough division into four age groups: yearlings, juveniles, young adults and adults (Storå [2001a](#); [2001b](#)). This age clustering does not correspond to actual chronological ages, since the skeletal growth and fusion of the epiphyses on pinnipeds is related to life history and their physical and sexual maturity, and therefore considerable differences can occur between individuals (Storå [2001a](#); [2001b](#)). A more precise age estimation was achieved by applying osteometric analysis. Size and growth variation on seal bones within the above-mentioned age groups help to distinguish seasonality of hunting patterns (Storå [2001a](#)). This analysis has been performed on humeri and femora, as these bones give secure determination at species level.

Due to excellent surface preservation of the bones, diverse modifications such as cut marks, tooth marks, and intentional breakages were recognisable and registered. All cut marks were recorded on sketches and some were photographed. Quantification of cut marks was carried out by counting those skeletal elements showing cut marks and not the number of cut marks on one bone. The specific position of cut marks on the bone helps to recognise and qualify killing and butchering patterns as well as to evaluate and differentiate processing patterns (skinning, filleting and scraping, dismembering; Binford [1981](#); Lyman [1987](#); [1992](#); Trolle-Lassen [1992](#)). The meat utility index for phocid seals (Lyman *et al.* [1992](#)) was utilised to reveal the economic significance of different body parts. That study

showed the rib cage to have the highest meat utility value, followed by the pelvis, the vertebrae and, in fourth place, the proximal limb bones. The lower limb bones have the lowest meat utility value. For the current study, the meat utility index was evaluated on the basis of NISP (Number of Identified Specimens).

Lipids extracted from interior surfaces and charred interior deposits from Ertebølle pointed based and Funnel Beaker pottery, recovered from the same archaeological context, have been analysed within the project 'Pottery Use among late Foragers and early Farmers in the Baltic'. Organic residue analysis of these lipids was analysed by gas chromatography mass spectrometry (GCMS) and GC combustion isotope ratio MS (GC-c-IRMS). Methods and results have been reported by Craig *et al.* (2011) and Heron *et al.* (2013).

3. Results

Out of 12,693 bones from mammals, birds and amphibians, 3847 bones have been identified. Altogether these bones are derived from 26 species of wild mammals (Table 1) and three species of domestic animals. A total of 1432 bones have been recovered from marine mammals, comprising 37% (NISP) and 26% (MNI) of all identified mammal bones. Marine mammals are represented by cetaceans: harbour porpoise (*Phocoena phocoena*) and dolphin (*Delphinus delphis*), and three species of pinnipeds: harp seal (*Pagophilus groenlandicus*), grey seal (*Halichoerus grypus*) and ringed seal (*Pusa hispida*).

Table 1: Identified species (mammals) in the faunal assemblage of Neustadt. Absolute and relative frequencies in terms of NISP and MNI

Species	NISP	% NISP	MNI	% MNI
<i>Erinaceus europaeus</i>	20	0.5	3	2.3
<i>Vulpes vulpes</i>	6	0.2	1	0.8
<i>Canis lupus f. familiaris</i>	234	6.0	5	3.8
<i>Canis lupus</i>	7	0.2	1	0.8
<i>Canis lupus/Canis lupus f. familiaris</i>	3	0.1	1	0.8

<i>Felis silvestris</i>	12	0.3	2	1.5
<i>Felis lynx</i>	3	0.1	1	0.8
<i>Castor fiber</i>	24	0.6	5	3.8
<i>Lutra lutra</i>	68	1.8	3	2.3
<i>Martes martes</i>	19	0.5	4	3.1
<i>Meles meles</i>	7	0.2	1	0.8
<i>Mustela putorius</i>	3	0.1	1	0.8
<i>Capreolus capreolus</i>	242	6.2	9	6.9
<i>Cervus elaphus</i>	798	20.6	13	9.9
<i>Alces alces</i>	54	1.4	3	2.3
<i>Sus scrofa</i>	521	13.4	14	10.7
<i>Bos sp.</i>	182	4.7	3	2.3
<i>Bos primigenius</i>	176	4.5	13	9.9
<i>Equus ferus</i>	1	0.0	1	0.8
<i>Ursus arctos</i>	1	0.0	1	0.8
<i>Phocidae (indet.)</i>	913	23.6		
<i>Pagophilus groenlandicus</i>	243	6.3	18	13.7

<i>Halichoerus gryphus</i>	116	3.0	7	5.3
<i>Pusa hispida</i>	20	0.5	2	1.5
<i>Phoca vitulina</i>				
<i>Delphinus delphis</i>	3	0.1	1	0.8
<i>Phocoena phocoena</i>	137	3.5	6	4.6
<i>Clethrionomys glareolus</i>	3	0.1	1	0.8
<i>Apodemus flavicollis</i>	1	0.0	1	0.8
<i>Arvicola terrestris</i>	33	0.9	6	4.6
<i>Microtus agrestis</i>	1	0.0	1	0.8
<i>Ovis/Capra</i>	12	0.3	2	1.5
<i>Bos primigenius f. taurus</i>	11	0.3	1	0.8
Total	3874		131	

Marine fish dominate the assemblage, with species like cod (*Cadidae* sp.), flatfish (*Pleuronectidae* sp.), garfish (*Belone belone*), herring (*Clupea harengus*) and mackerel (*Scomber scombrus*) (Schmölcke *et al.* [2007](#)). Some migratory fish were also present, including eel (*Anguilla anguilla*) and salmon species (Schmölcke *et al.* [2007](#)). Freshwater fish are represented by perch (*Perca fluviatilis*), zander (*Sander lucioperca*) and cyprinids (*Cyprinidae*). From all species recovered, marine species predominate, with cod at 69%, while freshwater fish contribute approximately 4% (Schmölcke *et al.* [2007](#)).

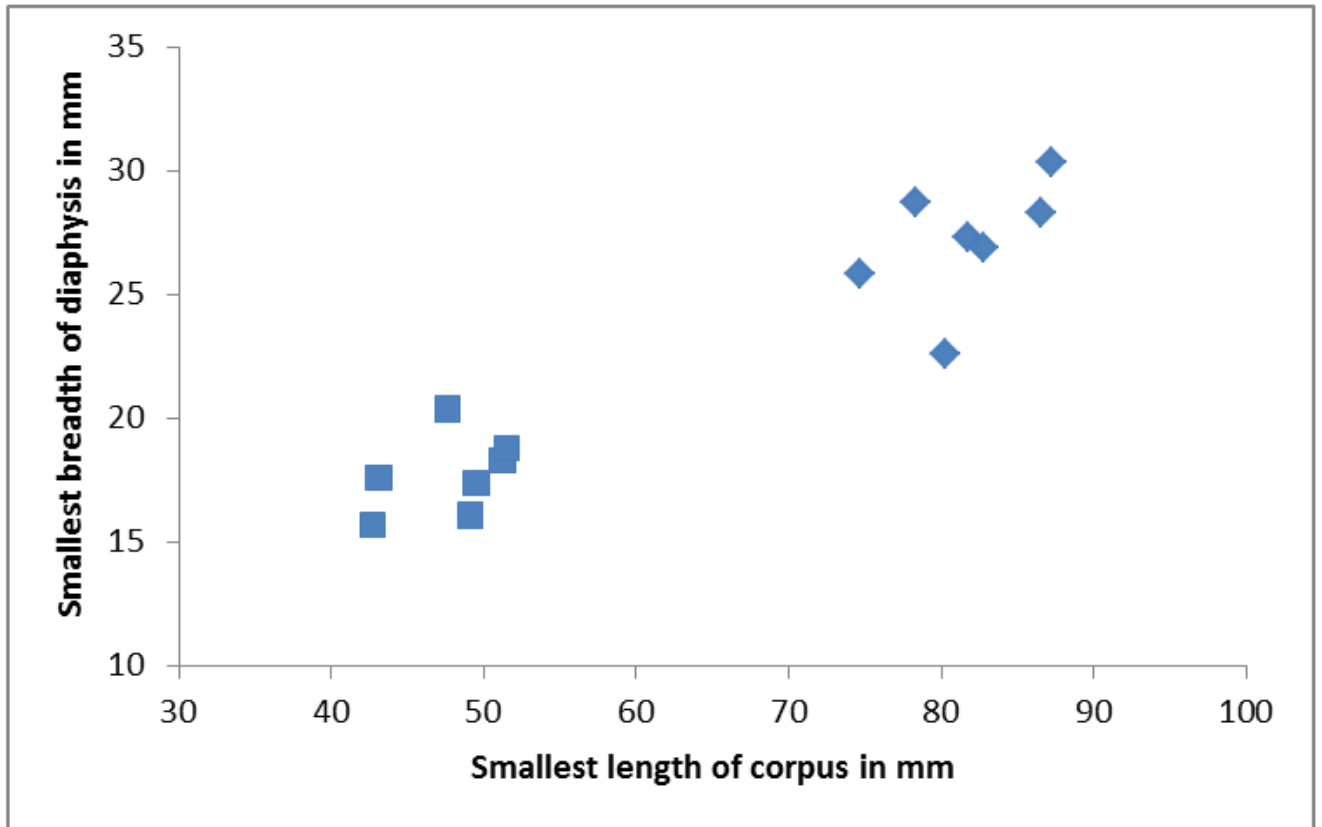


Figure 1: Measurements of harp seal femora from Neustadt. Key: squares = yearlings; rhombus = adults. Measurements after Ericson and Storå (1999) (Image credit: A. Glykou)

Table 2 describes the age estimations of epiphyseal fusion. Bones with still open epiphyses can belong to animals younger than the estimated age of fusion, while bones with fused epiphyses can belong to animals older than the estimated age of fusion. Hence, the actual age of seals found in this archaeological context can differ from the age clustering derived by ageing based on epiphyseal fusion, which reflects all age groups, yearlings, juveniles, young adults and adults (Table 2). Since ageing of seals based on epiphyseal fusion gives only a rough age estimation, an osteometric analysis has been applied on humeri and femora (Storå and Ericson 2004; Storå 2001a). The distribution of the osteometric data shows clearly that the harp seal assemblage is dominated by two groups in Neustadt (Figure 1). A comparison with modern data obtained from harp seals trapped in fishing equipment in Tromsø, Norway, in 1987 and published by Storå (2001a) allows us to identify an age group of yearlings up to 10-11 months old and an age group of adults. Furthermore, according to these modern data, the smallest bones within the age group of yearlings (blue squares), which have a smallest length of corpus under 45mm correspond to seal pups up to 3 months old, while the largest ones correspond to juveniles up to 10-11 months old (Figure 1). The age group of young adults is not represented among the harp seals of Neustadt.

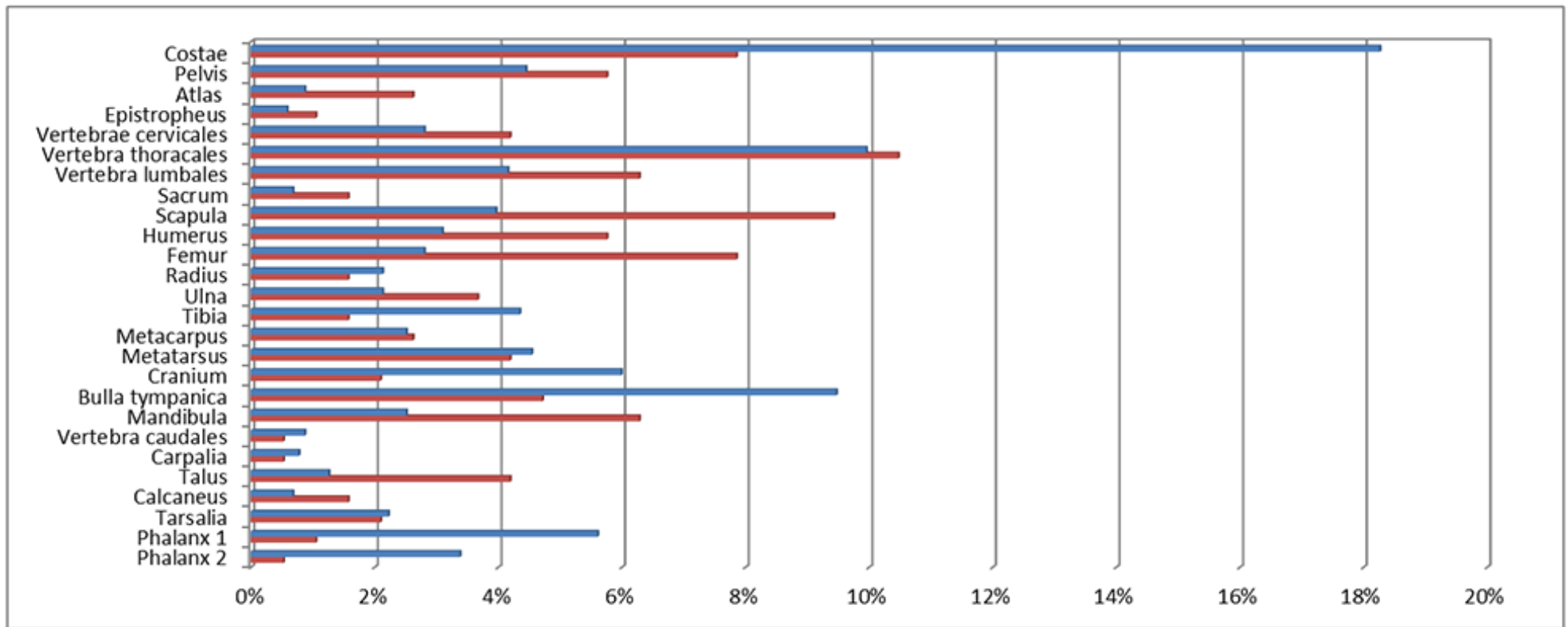


Figure 2: Frequencies of the relative importance of skeletal elements (blue) shown in % NISP (n = 1035) of all phocid seals and relative importance of skeletal elements with recorded cuts marks (red) shown in % NISP (n = 191). The skeletal element ranking reflects the meat utility values starting with the most flesh rich elements, the ribs (after Lyman *et al.* [1992](#)) (Image credit: A. Glykou)

Osteometric analysis of grey seal bones showed the presence of yearlings as well as adults. The analysis could not be performed for ringed seals.

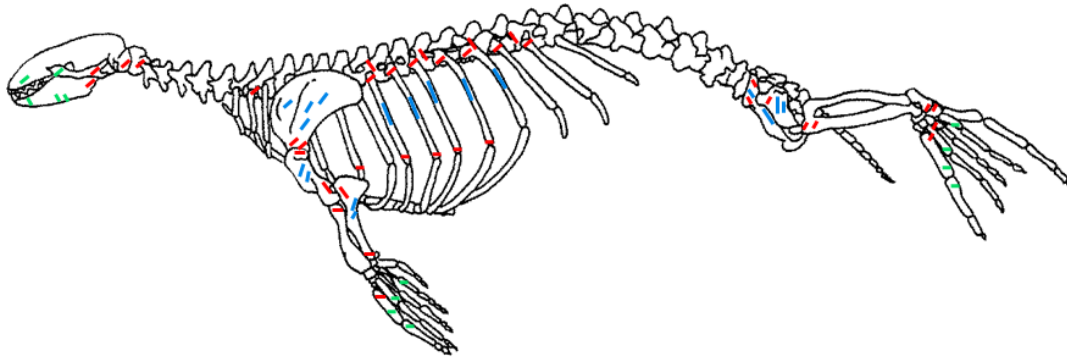


Figure 3: Phocid seal skeleton (modified after Boyle [2005](#)) showing location of possible cuts indicating skinning (green), dismemberment (red) and filleting (blue) (Image credit: A. Glykou)

Cut marks were recorded on 14.8% of the seal bones (Figure 2 and Figure 3), which is a very high percentage, if one considers that this includes only the visible butchery marks in an archaeological context (Lyman [1992](#), 248). All three species, harp, grey and ringed seals, disclosed no differences in the position and kind of cut marks on the skeleton, showing that hunters followed a common method for all marine mammals. Cut marks were observed on bones from all ages including the younger age group of 0-3 month old seals (Figure 4, Figure 5 and Figure 6). Frequencies and the type/position of cut marks on the bones reveal their origin during skinning, disarticulation and filleting, showing that hunters took full advantage of the seal carcasses (Binford [1981](#); Trolle-Lassen [1992](#)). Cut marks referable to skinning (Figure 3, Figure 5) were observed on the skull (calvaria, maxilla and frontal), the mandible, the phalanges and metapodials. After removing the skin from the prey, hunters proceeded with the butchering which included disarticulation, filleting and eventually portioning. Cut marks referable to disarticulation occur while cutting through the articulations and appear regularly on the occiput, the majority of vertebrae, scapula, humerus, radius, ulna, acetabulum of the pelvis, femur, talus, calcaneus and lower epiphyses of metapodials (Figure 3). They appear as short cuts around the articulations and are therefore easily distinguishable from filleting and/or scraping marks, which are commonly evident on skeletal elements rich in flesh. Such cuts appear on the scapula (Figure 6), humerus, femur, ulna, pelvis, on vertebra and the medial side of the costae. In these cases the cuts are more longitudinal and shallower than the ones originating during disarticulation, and often appear as a group of extended cuts. According to the meat utility index for phocid seals (Lyman *et al.* [1992](#)) the absolute and relative frequencies of the different parts of the skeleton as well

as the frequencies of skeletal elements with cut marks illustrate that in Neustadt bones with high meat utility value, such as ribs, and the upper limb bones, are well represented while the pelvis, second in the rank of meat rich body parts, seems to be under-represented. Interestingly, bones with lower (vertebrae) or low meat utility values (lower limb bones (flippers)) are frequently represented as well ([Figure 2](#)). The significance of these observations for the butchering methods used by prehistoric hunters will be discussed below.



Figure 4: Femur from a juvenile harp seal with cut marks. (Image credit: A. Glykou)

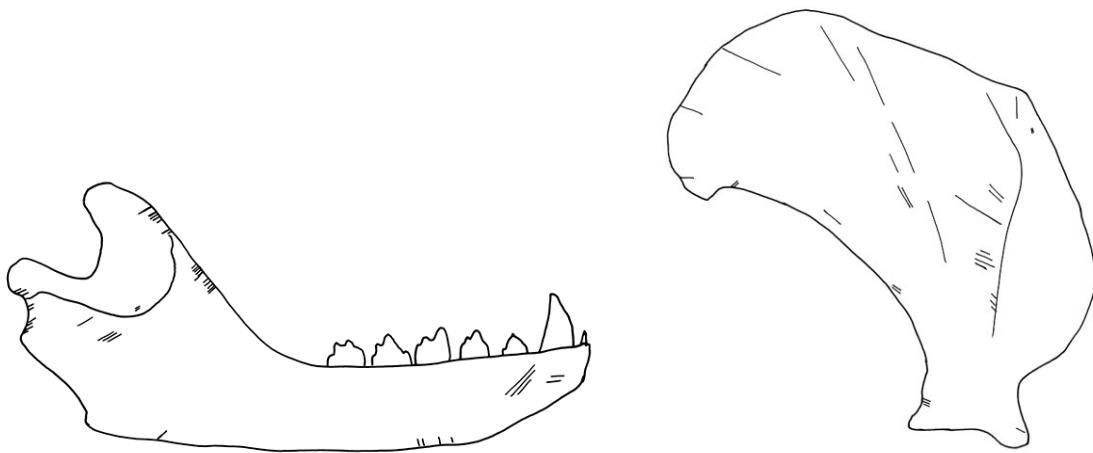


Figure 5: Dismemberment and possible skinning marks on a phocid seal mandible, lateral view. Cut marks from several finds. (Image credit: A. Glykou)

Figure 6: Dismemberment and filleting marks on phocid seal scapula, ventral view. Cut marks from several finds. (Image credit: A. Glykou)

Table 2: Absolute frequencies in terms of NISP and MNI of harp, grey and ringed seal epiphyseal fusion data (after Storå [2001a](#); [2001b](#)).

Element	Unfused		Fusing/fused		Age group
	NISP	MNI	NISP	MNI	
Harp seal					
Scapula distal	4	3	10	5	yearlings
Pelvis acetabulum	4	3	16	9	yearlings
Radius proximal	6	4			juveniles
Femur proximal	8	5	7	4	juveniles
Humerus distal	5	3	8	4	juveniles

Humerus proximal	4	2	8	5	young adult
Femur distal	8	5	7	4	young adult
Ulna proximal	2	2	4	2	young adult
Tibia/Fibula proximal	4	2	4	4	young adult
Ulna distal	1	1	5	3	adult
Tibia/Fibula distal	1	1	2	2	adult
Grey seal					
Scapula distal	5	3	6	3	yearlings
Pelvis acetabulum	4	2	6	4	yearlings
Radius proximal			3	3	juveniles
Femur proximal			2	1	juveniles
Humerus distal		2			juveniles
Humerus proximal	3	2			young adult
Femur distal			2	1	young adult
Ulna proximal			2	2	young adult
Tibia/Fibula proximal	6	3	2	2	young adult
Radius distal	1	1			adult

Ulna distal			2	2	adult
Tibia/Fibula distal	4	3	3	2	adult
Ringed seal					
Scapula distal			2	2	yearlings
Pelvis acetabulum			1	1	yearlings
Radius proximal	1	1			juveniles
Femur proximal	1	1			juveniles
Humerus distal	2	2	1	1	juveniles
Humerus proximal	1	1	1	1	young adult
Ulna proximal	1	1			young adult
Tibia/Fibula proximal	2	1			young adult
Tibia/Fibula distal	1	1			adult

4. Discussion

4.1 Presence of seals in the Baltic Sea

The presence of ringed, grey and harp seals in the Baltic Sea is related to the post-glacial development of the Baltic Sea basin and linked to climatic fluctuations during the middle Holocene (Lepiksaar [1986](#); Lõugas [1997](#); Ukkonen [2002](#); Sommer and Benecke [2003](#); Storå and Lõugas [2005](#); Schmölcke [2008](#)). The ringed seal was the first species that entered and reproduced in the Baltic Sea basin in a very early stage of its formation, the Yoldia Sea stage, when marine water entered the Baltic basin for the first time and a brackish environment

was established (Löugas [1997](#); Ukkonen [2002](#); Schmölcke [2008](#)). During the next stage, the Ancylus Lake, the connection to the Atlantic Ocean was closed after the glacio-isostatic land uplift of Scandinavia. Subsequently, the ringed seal remained the only seal species present in the Baltic Sea, i.e. in the Gulf of Bothnia and Finland until the late Atlantic climatic period (Ukkonen [2002](#); Sommer and Benecke [2003](#); Aaris-Sørensen [2009](#)). Appropriate environmental conditions for seals in the Baltic were established within the next millennia, known as the Littorina stage, when fluctuations of the Baltic Sea with saline water from the Atlantic Ocean, created gradually more marine conditions and a permanent connection between the Baltic Sea and the Atlantic Ocean was established. The frequencies of subfossil finds from harp and grey seals increased throughout the Baltic Sea after the Littorina Transgression, and showed that these animals started to reproduce in the Baltic Sea during the last stage of its formation.

Harp seal bones start to appear frequently during the Early Subboreal climatic period in several Swedish archaeological coastal areas (Fredén [1975](#); Ukkonen [2002](#); Aaris-Sørensen [2009](#)). Their occurrence in the Baltic Sea during this period is linked to the presence of a permanent harp seal population (Storå [2001a](#); Storå and Ericson [2004](#); Storå and Löugas [2005](#)). According to direct radiocarbon dates, the Baltic Sea harp seal population did not become established until the Subboreal climatic period (Bennike *et al.* [2008](#)). In fact, both direct dating and relative chronology revealed by the archaeological contexts show a regular presence of harp seals in the Baltic Sea between 4000–1800 cal BC (Storå and Löugas [2005](#)). The harp seal remains found in Neustadt are dated according to the archaeological context between 4400-3800 cal BC and thus belong to the oldest established harp seal population in the Baltic region (Glykou [2011b](#)). Later, during the Neolithic Pitted Ware Culture, harp seals appear in very high frequencies in numerous sites mainly on Gotland, Åland, as well as in the eastern Baltic (Storå [2001a](#); Ukkonen [2002](#); Storå and Lougas [2005](#)). In most of these cases the intensive seal exploitation is linked to the occurrence of harp seal breeding grounds in these regions (Storå and Ericson [2004](#)).

Seal-dominated faunas are known from several early and middle Mesolithic occupation sites in the northern Baltic, mainly in Finland, where the exploited seal species consisted of ringed and grey seals (Lindqvist and Possnert [1997](#); Ukkonen [2002](#); [2004](#)). From the south-western Baltic, seal remains are evident in numerous archaeological deposits but always represented by just a few bones in each case (e.g. Møhl [1970](#); [1971](#); Andersen [1995](#); Enghoff [2009](#); [2011](#); Trolle [2013](#)). According to the relative frequency of seals in Neustadt, hunting of harp and grey seals was a substantial part of the economy, representing the oldest evidence of extensive seal exploitation from the south-western Baltic Sea region. Another submerged site, also dated to the late Mesolithic Ertebølle culture, with high frequencies of seal bones (approximately one-third of the total faunal remains) derives from

the site Timmendorf-Nordmole I in the Wismar Bight at the Mecklenburg Bay (Schmölcke *et al.* [2007](#)). To what extent this new feature in the economies of the terminal Mesolithic in the south-western Baltic Sea region indicates a conscious change in the economy from terrestrial to marine, will be discussed below.

4.2 Ageing, kill-off patterns and seasonality

Using age estimations derived from epiphyseal fusion and osteometric analysis, two main age groups of harp seals, yearlings and adults, are represented in Neustadt. The same pattern was recognised for grey seals. In order to retrieve information on seasonality of hunting patterns, data on ecology and biology were derived from modern harp and grey seal populations. According to data from extant harp seal populations, females give birth on pack ice in February/March (Sergeant [1991](#)). If a similar breeding pattern is assumed for prehistoric harp seal populations in the Baltic Sea, then the seal pups up to 3 months old represented in the Neustadt assemblage must have been hunted during the spring. The yearlings up to 10-11 months old must have been hunted in the late autumn. If prehistoric and modern harp seal populations share the same migration patterns, then two different seasons of hunting, which depict the annual life-cycle of this highly migratory species and correspond to the two annual migration phases, can be recognised. One occurs in late spring: after they have formed their moulting rookeries and the moulting is completed, they migrate to the summer feeding grounds (Lavigne and Kovacs [1988](#)). The second migration takes place in early winter when they return to their breeding grounds to form their large breeding colonies (Lavigne and Kovacs [1988](#); Sergeant [1991](#)). It is far from clear in which season adult seals could have been captured, because ageing of young adults and adult animals can only be a rough estimation. Nevertheless, it is highly likely that adult harp seals were captured during the same seasons and in the same regions as the yearlings and juveniles because harp seals of all ages show similar social behaviour and migration patterns and consequently are likely to have been present and captured in the same seasons and in the same regions as the youngest ones. Furthermore, even if it is not possible to distinguish males from females osteologically, it is highly possible that some of the adult seals represent females captured during the breeding season together with their pups.

Grey seals are not migratory; they usually stay in the proximity of their breeding grounds and therefore adult grey seals might have been captured any time of the year. More precise information on the seasonal hunting of grey seals again highlights the yearlings age group. Within this age group 10-11 month old grey seals are apparent. Three modern grey seal populations, in the western North Atlantic, in the eastern North Atlantic and in the Baltic

Sea, exist independently of each other and give birth at different times of the year (Curry-Lindahl [1970](#); Anderson [1992](#)). Judging from the modern grey seal populations in the Baltic Sea, which give birth in February-March (Curry-Lindahl [1970](#); King [1983](#)), we can estimate a hunting season in late autumn for these seals.

Since ringed seal is represented by just a few bones it is not possible to retrieve any secure data about seasonality.

Apart from seals, marine mammals are represented at the site by a small number of bones from cetaceans. The lack of information on the ageing of cetaceans based on epiphyseal fusion data means that the age at death for either harbour porpoises or dolphins cannot be determined. The only information provided is based on a great number of unfused epiphyses from harbour porpoises, which indicates that these animals had not reached their full growth.

4.3 Hunting techniques and butchering patterns

How seals were hunted has been extensively presented and discussed in previous papers (Andersen [1997](#); Zagorska [2000](#); Glykou [2013](#)). Previous archaeological work relevant to this study has revealed several important hunting techniques used to capture and kill seals. In several Mesolithic and early Neolithic archaeological sites from Southern Scandinavia and northern Germany different types of harpoons have been recovered and interpreted as the main weapon for hunting seals (Andersen [1997](#); Ickerodt [2013](#)), particularly after a seal skeleton with a harpoon embedded in the scapula was found in Näpriö, on the west coast of Finland (Forstén and Ahlonen [1975](#); Zagorska [2000](#); Ukkonen [2002](#)). Harpoons made of roe deer antler and two half-finished examples made of red deer antler were among the finds from Neustadt and imply their use for marine mammal hunting (Glykou [2011b](#); [2013](#)).

An impact rib injury with a lithic projectile embedded in the bone has been previously seen as direct evidence for the use of a bow and arrow when hunting (Glykou [2013](#), fig. 6). Even if this hunting method is common for terrestrial mammals, it is the first time that we have such evidence for hunting marine mammals (Glykou [2013](#)). The Inuit are known to use a bow and arrow to hunt seals (Henshaw [2000](#)).

Observations on the fragmentation of skulls led to the conclusion that different hunting methods were used for different seal species. In fact the skulls of grey seals were extensively fragmented, unlike the postcranial skeleton and the skulls of harp seals. These fractures were caused before their deposition in the sediment. They cannot have originated during processing the skull in order to extract the brain because, firstly, one would have

expected that both grey and harp seal skulls should have been treated similarly, and secondly, extended fractures on the forehead do not exclusively occur when obtaining the brain. Consequently, the different preservation of skulls between harp and grey seals has been interpreted as the result of killing grey seals by hitting them on the forehead with clubs (Glykou [2013](#)), a practice widely known from ethnoarchaeological records and commonly used up to modern times (Clark [1946](#); Boyle [2005](#)). Grey seals prefer to breed on the coast and are thus easier to reach than harp seals, which breed on pack ice. These different species-dependent hunting practices suggest deep knowledge of the behaviour and habitat of the animals.

The presence of seal pups among the fauna indicates hunting during the breeding season. In this case not only pups but also females must have been killed, since female seals tend to stay close to their offspring during the lactation period and that makes them more vulnerable. Harp seals in particular form large colonies during the breeding season, making them available in large numbers for prehistoric hunters. All these observations on hunting strategies, together with the indication that different hunting methods were used between harp and grey seals, illustrate that prehistoric hunters were fully aware of the particular social behaviour and habitat of each species and show strong adaptation of their hunting practices to each species respectively.

Prey management in Neustadt can be reconstructed according to the observed position of cut marks on the skeleton and the frequencies of bones with high meat utility value. As mentioned above, all seal species were processed similarly and were exploited for their skin, meat and eventually blubber independent of their age. The frequencies of skeletal elements with rich and low meat utility values suggest that seals were brought whole from the kill site, either portioned in smaller and, thus, more transferable units or complete. Based on both ethnographic studies and archaeological evidence on Inuit household economies, it appears that the transport of the whole seal from the kill to the occupational site for processing was a common practice (Henshaw [1999](#)). An alternate hypothesis would be that seals were partly processed at the kill site, including skinning and perhaps dismemberment, since that would enable the hunters to transport adult harp and grey seals more easily. In this case, all body parts were transported to the site, including the flippers, which apparently remained attached to other units.

Unlike the bones from terrestrial animals, the long bones from pinnipeds do not show any recognisable intentional breakages that could have originated during bone marrow extraction, tool production or food portioning. This is most likely due to physiological and anatomical reasons. Pinniped bones have a much higher mineral density compared to bones from terrestrial mammals and the medullary cavity consists of trabecular bone, making the

breakage and extraction of bone marrow undesirable work for hunters (Lyman *et al.* [1992](#); Lyman [1994](#)), who could gain the required bone marrow more easily from terrestrial prey. Similarly, due to their short and compact shape, pinniped bones are not the most appropriate raw material for making tools, at least not when bones from red deer, elk, roe deer, and dog were available. Bones from such animals – mainly antlers, metapodial bones and ulna – were processed for tool production, as is evident from both the tools and bone debris resulting from tool production (Glykou [2011b](#)).

4.4 Ecozones of human activity and resource supply patterns

Using the faunal assemblage (Table 1), three ecological zones can be distinguished: terrestrial, near to the shore/inshore, and marine zones. The plant macrofossil and palynological analysis suggests the site was close to a mixed oak forest (Hartz *et al.* [2011](#)), thus giving the inhabitants of the site access to all three zones. Were prehistoric humans equally active and mobile in all three ecological zones or did they favour specific ecozones for their main prey?

Terrestrial resources were intensively exploited as shown by the frequencies of terrestrial mammals, accounting for approximately 63% (NISP) of the total mammal assemblage (Table 1). Besides that, the inhabitants benefited from other terrestrial resources by gathering hazelnuts and shed red deer antlers (Glykou [2011b](#)).

Seal hunting, as described above, was practised mainly near the shore, on the land in the case of grey seals or on pack ice in the case of harp seal pups, which spend their first weeks exclusively on ice (Sergeant [1991](#)), rendering them vulnerable and easy prey. Another activity that can also be ascribed to exploitation of near-shore resources is freshwater fishing. However, freshwater fish such as perch, zander and cyprinids are represented at extremely low frequencies, accounting for less than 4% of the fish species (Schmölcke *et al.* [2007](#)). Waterfowl birds consisting mainly of Anatidae indicate near-shore exploitation.

Cetaceans – dolphins and harbour porpoises – are pelagic species and their presence among the faunal remains of Neustadt suggests exploitation of marine resources. These species can be caught either offshore, if hunters are experienced and have the appropriate maritime technologies, or near to the shore, most likely when sick animals approach the coastline or when disorientated animals are trapped in shallow waters. Dolphins do not belong to the common fauna of the Baltic Sea but they are frequently encountered there, entering from the North Atlantic perhaps in search of food or following shoals of fish. Bones from big whales such as the killer whale have been found in the late Mesolithic sites of Tybrind Vig

(Trolle [2013](#)) and Ronaes Skov (Enghoff [2009](#)). It has been suggested that such whales might have entered the Baltic Sea attracted by the frequent presence of seals in this region (Trolle [2013](#)). In any case, since dolphins or bigger whales do not belong to the common fauna of the Baltic Sea, they could not have been hunted regularly there.

The small harbour porpoise – the only whale species common in the Baltic Sea – is represented in the faunal assemblage by at least six animals according to the MNI and has relatively high frequencies in terms of NISP (Table 1). Lots of the harbour porpoise bones display cut marks, showing that the animals were exploited by humans. Even if there is no direct evidence for hunting small whales, such as bone lesions caused by hunting weapons, their high frequencies demonstrate that they were a desirable and regular prey. Did hunters chase and kill harbour porpoises or did they take advantage of stranded or sick animals that had approached the shoreline? Late Ertebølle Culture hunters had already developed their maritime technologies and equipment to such a degree that they must have been able to undertake offshore trips. In several Mesolithic sites dugout canoes and paddles have been recovered (Andersen [2011](#); [2013](#)), demonstrating the maritime character of these sites and the mental orientation of hunters to marine resources. Harpoons, which have been interpreted as the principal hunting weapon used for seals (Andersen [1997](#)), might also have been utilised to hunt harbour porpoises. Still, offshore hunting trips targeting small whales can be perilous, demanding participation of several experienced hunters, boats and good coordination (e.g. Piana [2005](#)). Hunting harbour porpoises in the south-western Baltic Sea could not have been as dangerous as hunting big whales in an ocean, but it could not have been carried out by one hunter alone. Hunting harbour porpoises in historical times occurred in the narrows of the Little Belt in Denmark by taking advantage of the migration of the porpoises and the narrow topography of the region, which made the capture of porpoises easier (Trolle [2013](#)). Because of the lack of any evidence of specialised offshore hunting trips targeting small whales, it would be reasonable to assume either that harbour porpoises were captured near the shore and eventually killed by spearing them with harpoons from the boats or that hunters simply exploited stranded animals.

Besides the presence of cetaceans, the economic importance of offshore/marine prey for the inhabitants of Neustadt is also evidenced by the presence of marine fish species such as cod, flatfish, herring, garfish and mackerel. Marine fish dominate the fish assemblage and indicate high marine conditions for the Baltic Sea at the time the site was occupied (Schmölcke and Ritchie [2010](#)). Hence these highly marine species could have been caught either offshore by using dugout canoes or near the shore, provided that fishing took place during their spawning seasons.

Consequently, the exploitation of aquatic resources consisted partly of inshore/near-shore prey, such as freshwater fish and waterfowl birds, but mainly targeted highly marine resources such as marine fish and marine mammals. Marine prey was most likely caught inshore, taking into account the availability of various resources in this ecozone. At the same time, such a subsistence strategy reduces the high risk to the hunters associated with hunting or fishing in open waters. In this manner the ecological zones of human activity and the ecological zones of resource supply are diversified.

4.5 Specialised, selective or opportunistic?

Specialised hunting is used to characterise a faunal assemblage dominated by one species (Rivals *et al.* [2004](#)), while the term 'specialised' is used to characterise the function of a site if one particular activity dominates (hunting, fishing, etc.). Selective hunting refers to prey selection patterns targeting specific nutrient resources (meat, bone marrow, blood and organs) or raw materials (fur, skin, bones for tool industry, fat and blubber) within a faunal assemblage based on age structure and seasonality. Specialised hunting does not necessarily involve selective hunting if there is no prey selection based on age and sex (Rivals *et al.* [2004](#)). Game acquisition processes are very complex as they depend on numerous ecological (seasonal migrations and social behaviour of game), topographical (game accessibility) as well as anthropological factors (hunter's perception of hunting, degree of understanding of animal behaviour, available hunting equipment), many of which are difficult or impossible to detect in an archaeological context. Still, utilisation of as much as possible of the available information derived from an archaeological context can contribute significantly to a more holistic reconstruction of the exploitation patterns. In order to explore whether exploitation of marine mammals in Neustadt implies specialised hunting and/or whether it is possible to recognise prey selection patterns, some key aspects were considered together: a) relative abundances and diversity of the entire faunal assemblage b) economic significance based on cut marks, c) age structure and seasonality based on kill-off patterns, d) palaeoecological approach in relation to the natural abundance of the game at the time of use of the site, and/or specific seasonal game behaviour, and e) character of the site as it is reconstructed based on all available find categories.

The relative abundances of the mammalian faunal assemblage show dominance of terrestrial game both in terms of NISP (61.5%) and MNI (65%). Additionally, the broad range of species represented in the faunal assemblage implies diverse hunting, both in terms of NISP and MNI. Consequently, both the high diversity of the faunal assemblage and the dominance of terrestrial fauna among the hunted mammals provide no evidence for specialised seal hunting in Neustadt. Nevertheless, the high frequencies of marine mammals, with 37% NISP and 26% MNI, together with fish, as well as the ratio of marine to

terrestrial, which is estimated for selected sectors of the site at 10:1 by individual skeletal parts (NISP) – show the focus was strongly on the exploitation of maritime resources.

As far as the economic significance is concerned using the analysis of cut marks, the same processing patterns, skinning, dismemberment and defleshing, are consistent across all age groups of seals. Thus, fur from pups, skin from sub-adults and adult seals, and meat from all age groups were fully exploited by the hunters. Hence, no prey selection depending on a specific resource (fur, skin, meat) or specific age group could be identified among the seals.

The presence of two main age groups of harp seals, yearlings and adults, has been linked to two different hunting seasons, one in late autumn and one in spring, based on the annual life cycle of these seal species: birth-migration-return to breeding grounds. These two hunting seasons have been interpreted as potentially having different supply targets (Glykou [2013](#)): hunting in spring could be primarily aimed at obtaining meat and skin, on the grounds that during the breeding and the following moulting period the total weight of adult female seals decreases to a dramatic extent (Sergeant [1991](#)). Hunting in autumn could primarily have been aimed at seals' fat reserves (Glykou [2013](#)), since seals feed heavily during the summer in their summer feeding grounds and reach their maximum weight when they come back to their breeding grounds (Sergeant [1991](#)). Do the two hunting seasons really reflect a conscious choice of the hunters, who aimed at specific resources – primarily meat or blubber depending on the season?

By contemplating the annual life cycle of harp seals, which start their migration after moulting is completed in late spring, and return to their breeding grounds in late autumn, then harp seals were present at their breeding grounds during these seasons. Considering that a harp seal breeding colony existed close to the site (Glykou [2011b](#)), it can be assumed that hunters in Neustadt simply took advantage of the natural abundances of seals and resource availability near to their occupation or catch sites. Consequently, harp seal hunting in spring and autumn corresponds to the seasonal migrations of the species.

The character of the site has been reconstructed based on all available find categories (Glykou [2011b](#)): Plant remains and palynological analyses showed that the site was near a mixed oak forest (Hartz *et al.* [2011](#)). That offered the inhabitants of the site a varied diet and ideal opportunities for gathering and exploiting raw material resources such as wood, deer antlers and hazelnuts (Glykou [2011b](#)). Thus, Neustadt presents an ideal example of the coastal hunting and fishing stations of the terminal Mesolithic and earliest Neolithic commonly found in southern Scandinavia, which predominantly concentrate at coastal marine or freshwater systems (Andersen [1995](#); [2008](#); Terberger *et al.* [2009](#)), and take advantage of both terrestrial and marine ecosystems.

In conclusion, the high frequencies of seals, and especially harp seals, in Neustadt are to be seen as the result of opportunistic hunting patterns, as obviously hunters took full advantage of the existing available natural resources.

4.6 Roasting or boiling?

An essential part of subsistence is food preparation. The sum of evidence obtained from the archaeological context together with the different find categories help us to comprehend and reconstruct resource management practices. A very specific aspect is how the prey has been processed as food or as a raw material resource and which analytical tools are available to explore the stages between butchering and discarding bones after food consumption.

Burnt or partially burnt bones in a faunal assemblage may signify roasting units consisting of meat and bone. Parts of the bones, such as articulations, might, after dismemberment and portioning of the prey, be partially defleshed. These bones burn to some degree when exposed to fire during roasting. The colour of burnt bones reflects the temperature to which they have been exposed (Lyman [1994](#)). In the faunal assemblage of Neustadt, burnt or partially burnt bones display colours that vary from deep blue/black, black, black/greyish, while calcined bones were rare. All these are indications of bones exposed to intense heating ($\geq 600^{\circ}\text{C}$) (Shipman *et al.* [1984](#)). However, partially burnt bones in Neustadt are extremely rare, most likely indicating that boiling was the most common practice for food preparation. During boiling the bone diagenesis is low because of less intense heating ($< 400^{\circ}\text{C}$) and thus there are no obvious or recognisable traces on the bone surfaces (Shipman *et al.* [1984](#); Koon *et al.* [2003](#)). Consequently, we can either assume that meat-bone units were cooked in pots, or that meat off the bone was boiled, most probably combined with other ingredients (Saul *et al.* [2013](#)), since we know from a large number of bones with scraping and filleting marks that meat was removed from bone prior to cooking. Roasting and boiling of portioned units have been recorded as a common practice for food preparation in middle and late Mesolithic sites from southern Scandinavia (e.g. Noe-Nygaard [1995](#); Magnell [2003](#)).

Ceramic vessels as a new element appear in archaeological contexts in southern Scandinavia during the second half of the fifth millennium BC. Neustadt represents one of the largest and well-preserved ceramic assemblages of the late Ertebølle and earliest Funnel Beaker Cultures. These vessels have been interpreted as cooking vessels because of the frequent appearance of charred deposits in the interior and exterior, and traces of soot, demonstrating that the pots were exposed to fire. The ceramic assemblage consists of

pointed-based vessels, shallow oval-shaped vessels known as 'lamps' and a variety of funnel beakers (Glykou [2010](#); [2011a](#); [2011b](#)).

Both cooking vessels and oval-shaped lamps were selected for organic residue analysis. Organic residue analysis of lipids extracted from ceramic interior surfaces and charred interior deposits or 'foodcrusts' by gas chromatography mass spectrometry (GCMS) and GC combustion isotope ratio MS (GC-c-IRMS) from Neustadt has been reported by Craig *et al.* ([2011](#)). Identifications were made by considering the isotope ratios of individual fatty acids (Craig *et al.* [2011](#), fig. 2) or the presence of specific biomarkers (Craig *et al.* [2011](#)). A comparison of lipids recovered from pointed-based EBK and TRB Funnel Beaker pottery from Neustadt shows that marine and ruminant products were a feature in the diet during both periods (Craig *et al.* [2011](#), table 1, fig. 2). This reflects the results of a much larger sample showing continuity in the processing of marine foods after the introduction of domesticated animals (Craig *et al.* [2011](#)). The technique used cannot distinguish between marine mammals and marine fish. However, a small number of lipids extracted from cooking vessels from Neustadt demonstrate isotopic characteristics that match reference values for marine mammals; therefore the processing of seal blubber in the pottery is highly likely. Additionally, similar analysis of four lamps from Neustadt revealed the presence of lipids derived from an aquatic source (Heron *et al.* [2013](#)), which have been interpreted as evidence for the use of seal blubber for lighting. The ceramic assemblage at Neustadt provides extensive evidence for processing seal blubber, although about twice as many pots were used to process terrestrial as opposed to marine resources.

5. Conclusions

The chronology of Neustadt (4400 cal BC to 3800 cal BC) means the site represents the oldest archaeological context in the south-western Baltic Sea region for which there is extensive evidence for harp seal hunting, and suggests a connection to the oldest harp seal population in the Baltic Sea. Bone fragmentation shows that hunting strategies were fully adapted to the social behaviour and habitat of each seal species. Two hunting seasons for grey and harp seal, one in spring and one in late autumn, could be recognised. Even if the two hunting seasons imply diversified supply targets (primarily meat and fur in spring and mainly blubber in autumn) there is no evidence of selective hunting. Most likely, the high frequencies of seals reflect their natural abundance in the region, considering that Neustadt was connected to a harp seal breeding colony. The subsistence in Neustadt during the transition to agriculture seems to remain stable. Neolithic elements such as Funnel Beaker pottery and just a few bones from domesticated cattle, sheep and goat indicate a gradual change in the economy. This observation is in accordance with the lipid analysis performed

on pottery from the same archaeological context, which showed that much Funnel Beaker pottery was used to process wild terrestrial and marine resources.

Acknowledgements

The study was part of PhD thesis funded by the DAAD (German Academic Exchange Service) and the Graduate School 'Human Development in the Landscapes', Christian-Albrechts-University of Kiel, Germany. I would like to thank the staff of the Archaeological State Museum Schloss-Gottorf in Germany for hosting me and supporting my work in many different ways. Special thanks are due to U. Schmölcke for the fish identification, to W. Lage for helping me to increase my knowledge of mammal bones identification, to S. Hartz for fruitful discussions and I. Ulbricht for supporting my work and providing access to archaeological material. The project 'Pottery Use among late Foragers and early Farmers in the Baltic' was funded by the Arts and Humanities Research Council (ARCH) and I would like to thank all the researchers involved in this project. O. Craig is owed special thanks for his support and his valuable comments on this article. Many thanks to S. Harris and E. Dimitriadi who improved the English. My gratitude to two anonymous reviewers whose comments helped me to improve this article.

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