Dynamic adaptations of the Mesolithic pioneers of Gotland in the Baltic Sea

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ABSTRACT – *Mesolithic pioneers reached Gotland around 9200 cal BP and adopted seal-hunting. The subsistence economy was flexible, and the importance of freshwater fish is reflected in the location of settlements and available stable isotope data. Overgrowing lakes provided an important subsistence base, and marine resources were mainly related to raw material needs. The narrower breadth of resources is reflected in the osseous production, where implements were made from seal bones. The lithic technology exhibits local adaptations over time – in the form of a simplification of the technology – that we relate to sedentism and increases in risk management and external networks.*

KEY WORDS – *lithic technology; osseous technology; marine adaptation; seal exploitation; Stora Förvar; Mesolithic*

Dinamične prilagoditve mezolitskih pionirjev na območju Gotlanda ob Baltskem morju

IZVLEČEK – *Mezolitski pionirji so dosegli Gotland ok. leta 9200 pr. n. št. in so prevzeli lov na tjulnje. Njihovo samooskrbno gospodarstvo je bilo prožno, pomen sladkovodnih rib pa se kaže tako v lokacijah naselbin kot podatkih o stabilnih izotopih. Zaraščena jezera so nudila pomembno osnovo preživetja in morski viri so bili predvsem povezani s potrebo po surovinah. Slabše dostopni visi se kažejo v produkciji kostnih izdelkov, ki so bili izdelani iz tjulnjevih kosti. Kamnita orodja pa kažejo lokalne prilagoditve skozi čas – v obliki poenostavljanja tehnologije -, ki jih povezujemo s stalnim načinom življenja in povečanjem upravljanja tveganj ter zunanjih omrežij.*

KLJUČNE BESEDE – *tehnologija izdelave kamnitih orodij; tehnologija izdelave koščenih orodij; prilagoditev na morje; izkoriščanje tjulnjev; Stora Förvar; mezolitik*

Introduction

The aim of the project "*The Pioneer Settlements of Gotland*" was to achieve a deeper knowledge and understanding of the oldest Mesolithic settlements on the island of Gotland in the Baltic Sea (Fig. 1). By combining renewed investigations of archaeological materials from old sites with new excavations of selected sites the goal was to present a novel view of the first pioneers of Gotland and their relations to groups on the mainland. A central site for the project was the cave site of Stora Förvar located on Stora Karlsö, a small island *c.* 5km west of Gotland, with rich cultural layers containing the earliest evidence of humans on Gotland. Here we summarize the most important implications of understanding of the pioneer settlements on the island of Gotland. The present study is based on an earlier summary presented in Swedish (*Apel, Storå 2017*) that has been complemented with additional information.

The island of Gotland was one of the last unexplored territories in Scandinavia and the Baltic area that was colonized by humans during the post-glacial pe-

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riod. The pioneer settlement phase of Gotland extends between 9200 and 7600 cal BP. Gotland rose out of the Baltic Ice Lake in the pre-Boreal period and was never connected to the mainland. Since the island is positioned 80 km from the nearest mainland, *i.e.* the Swedish east coast, large terrestrial mammals were not present on the island until hare and fox appeared during the Middle and Late Mesolithic period (*Ahlgren* et al. *2016; Lindkvist, Possnert 1997*), possibly introduced to by humans. The environment and climate in the Baltic Sea area was undergoing major changes at the time of the initial pioneer settlements. During the Late Boreal time (9200-8200 BP), Gotland was covered by a light forest consisting mainly of pine in the coastal areas and birch, elm, oak and hazel at the fertile soils of the inland (*Påhlsson 1977; Österholm 1989.14*). The annual average temperature was similar to that of today, but with slightly cooler winters and warmer summers. The Baltic Sea was a freshwater lake, the Ancylus Lake, but a gradually rising temperature meant that the Atlantic sea level rose and after about 8500 BP, salt water flowed into the Baltic Sea through Öresund (*Andrén* et al. *2011*). These large-scale changes are important for understanding the development and character of the environment and the settlements, even if in the present work we are examining a specific region. In this paper we summarize our results of the research project against the background of previous arguments and interpretations of the Mesolithic period in the Baltic region.

Chronology of the cave Stora Förvar

The cave site Stora Förvar has been a key site and frame of reference for Stone Age research in Scandinavia, despite the fact that the place in many respects is unique. The cave was excavated between 1888 and 1893 by Lars Kolmodin, a schoolteacher from Visby, and Hjalmar Stolpe, one of Sweden's foremost field archaeologists in the late 19th century (*Schnittger, Rydh 1940*). The cave is *c*. 25m deep and the original cultural layer, which was over 4m thick, was excavated in sections (A-I) and in 0.3 meter spits (a Swedish foot) (*Schnittger, Rydh 1940*).

The stratigraphy in the cave was obviously formed over a long period of time, but it was still difficult to establish a relative chronology. For a long time the stratigraphic integrity of the cave was questioned, partly because of the original excavation method, but also because of how the finds had been handled after the excavations (see *Lidén 1942; Rydbeck 1950; Althin 1951*). However, subsequent research has clarified the stratigraphic conditions (*Knape, Ericson 1988; Lindqvist, Possnert 1997; 1999; Apel, Storå 2017; 2018; Apel* et al. *2017; Boethius* et al. *2017; Landeschi* et al. *2017; 2018*).

An important aim of the project has been to evaluate the integrity and character of the Mesolithic cultural layers in the cave. Therefore, a small excavation in the cave floor was conducted in the summer of 2013 (*Apel* et al. *2015*) (Fig. 2). On previous visits seal bones and worked flint had been observed in the soil between the stones in the cave floor, and this indicated that there could be preserved pockets of cultural layers that were not excavated during the original excavation. The purpose of our new fieldwork was thus to investigate this more closely.

Three small test pits (Fig. 2) were excavated, two of which were located at the bottom of the cave and found to contain intact Mesolithic layers. The culture layers in the test pits were water sieved in 4 and 2mm meshes, and the findings were collected in units of 0.5x0.5m and in 5cm spits. Using a mobile 3D scanner, a digital, three-dimensional model was created of the cave (*Landeschi* et al. *2017; 2018; Lundström 2016*). The purpose of the model was to reconstruct the cultural sequence documented in the original excavation, and thus give us an opportunity to more closely link archaeological finds to their original positions in the cultural layer. The cultural layers in the two inner test pits consisted of sand and soot. In several places, lime originating from the

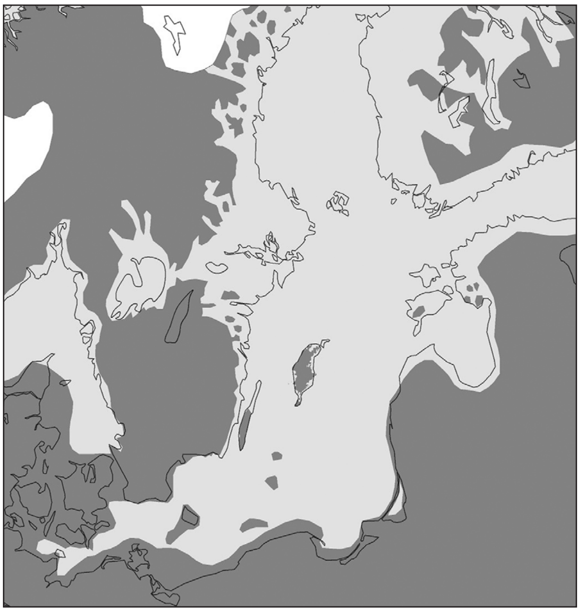

Fig. 1. The Baltic Sea with modern and early Holocene (grey) coastlines. Gotland is the large island in the lower centre of the figure.

cave's walls had infiltrated the cultural layer, thus preserving pockets and lenses of cultural layers. The existence of intact pockets with remnants of Stone-Age finds and soil matrix in the cave floor was an important finding which offers new opportunities to obtain important information about the early use of the cave.

A series of radiocarbon dates of finds from the bottom layers of the stratigraphy of the cave date to the period 9200–7800 cal BP (*Apel* et al. *2017; Lindqvist, Possnert 1999; Landeschi* et al. *2018*). Thus, the cave was used during the early and middle Mesolithic periods but from the late Mesolithic period there is an approximately 2000-year long hiatus in the sequence. The cave was not in use again until the early Neolithic period (*c.* 6000 cal BP) and onwards. In connection with the 2013 excavation, six radiocarbon dates were analysed: A seal bone and a human tooth from Trench 2 and a salmon bone from Trench 3 were dated to the interval 9200–9000 cal BP (*Apel* et al. *2015; Apel, Storå 2018; Apel* et al. *2017; Boethius* et al. *2017*). Four additional samples of seal and sheep bones collected *in situ* in limestone concretions in the cave walls were also selected for radiocarbon dating. These dates confirmed that the lower meter of the stratigraphic sequence can be dated to the earliest Mesolithic phase, while samples from *c.* 1.2m and upwards are of younger age (*Apel* et al. *2015*). Thus, the transition in the stratigraphy between the Mesolithic and Neolithic phases should appear somewhere between 0.6–1.2m above the cave floor, depending on location in the cave. As the cave floor slopes towards the mouth, the Mesolithic layers are thicker there while thinner at the end of the cave. This is further confirmed by a digital analysis of the distribution of ceramics in the cave sequence (*Landeschi* et al. *2018; Lundström 2016*) and also by analysis of the animal bones in different parts of the cave (*Apel, Storå 2018*). A summed probability distribution model of all available radiocarbon dates from the cave suggests that the hiatus may have been somewhat shorter than previously estimated, probably around 1400 years (Fig. 3). We thus have a better idea than before about the stratigraphic and chronological conditions in the lower layers of the cave. However, the upper layers from the Late Stone Age to the Iron Age/Middle Ages are not yet as well investigated or documented.

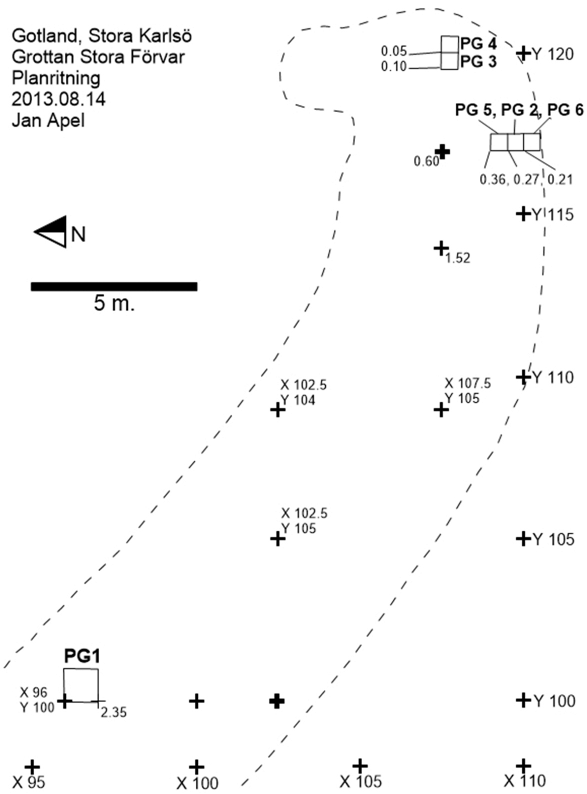

Fig. 2. Plan drawing of the Stora Förvar cave and the trenches of the 2013 excavation.

Stratigraphic integrity and observations of the 2013 survey at the Stora Förvar cave

During the 2013 excavation, stone and flint artifacts, burnt clay and pottery, bones of animals and humans were recovered (see *Apel* et al. *2015*). The flint consisted mainly of local Ordovician flint, but some fragments in south Scandinavian flint were also found. A large proportion of cores and flakes with cortex indicate that beach pebbles were used as raw material. Approximately 8.5kg of bone material was collected, and the bones of seals and hare, fish and birds but also occasional domestic animals such as sheep/goats, cattle and pigs were recovered. These last mentioned bones are obviously recent intrusions that were deposited in the cave floor after the primary excavations. A few skull fragments, a milk tooth and fragmented foot bones from humans were also recovered. The tooth was dated to *c.* 9300–9200 cal BP (BETA-399029, 8420±40 (*–300 years to compensate for the freshwater effect*); *Apel* et al. *2017*), one of the oldest dates of a human bone from Stora Förvar and Gotland.

In the material from 2013, grey seals and ringed seals are most common, while harp seals were not identified with certainty. This is in good agreement with previous observations of the faunal assemblages in the Mesolithic layers (*Pira 1926; Possnert, Lindqvist 1997*). The fish bone material contains a few elements of (large) salmon, which are common

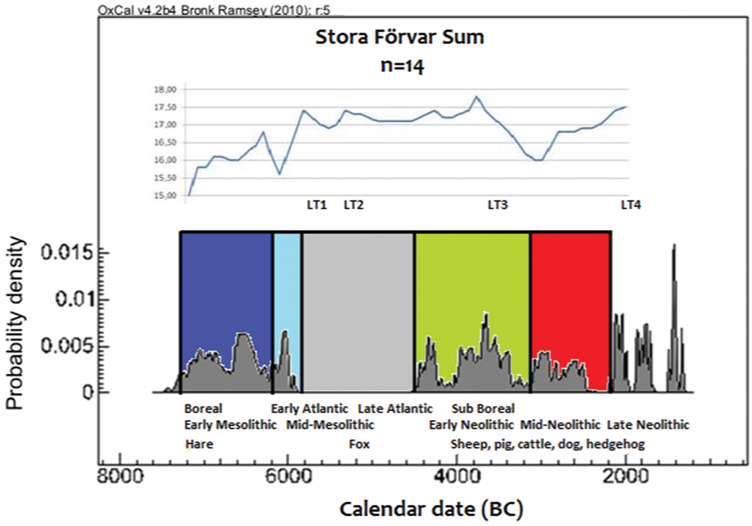

Fig. 3. A summed probability distribution model based on 68 radiocarbon dates (14 binned 200-year slots) from the Stora Förvar cave (*Apel *et al.* 2017*).

on Mesolithic sites but unusual on Neolithic ones (*e.g.*, the middle Neolithic Pitted Ware culture sites). An important observation that testifies to the integrity of the recovered pockets with Mesolithic finds and layers is that some long bones from young grey seals with conjoining unfused and loose epiphyses were recovered. As these parts of the elements were found in close proximity to each other, extensive (post-depositional) disturbance does not appear to have occurred. The refitting of two flint blades is another indication of stratigraphic integrity (Fig. 4). However, occasional finds of pottery and bones from domestic animals and cod from later periods show that the lowest layers in the inner part of the cave consist of a palimpsest. Moreover, artefacts made of sheep/goat bone have been identified in the old find material, although they appeared in the top layers of the stratigraphy, see below. These finds may actually be old intrusions, but perhaps more likely they were trampled into the soil after the excavations. The excavations in 2013 together with more detailed analyses of the archaeological finds from the first excavations show that the finds from Stora Förvar provide the most important frame for chronological analyses. The other sites on the island of Gotland, even with considerably smaller amounts of finds, may be compared and associated with the cave sequence, but they also complement the chronology of the settlement.

The lithic technology on Gotland during the Mesolithic

The stone finds from the 2013 excavation provide interesting insights into the character of the settlement. Two flake cores in local flint testify to a reduction technique similar to that of the technology group 2 of the younger Maglemosian culture of southern Scandinavia (upper part of Figure 4; see *Sørensen 2006*). These are cores with flat, unprepared platforms, and with about 70° external platform angles and step-fractures on the reduction surface. These features suggest the use of a direct technique with soft hammer percussion; probably a hammerstone in sand- or limestone or less likely a hammer of moose/red deer antler. Two of the blades recovered during the investigations have been possible to refit, indicating that knapping occurred in the cave itself, and also the integrity of the cultural layer. Interestingly, flint technology seems to have been simplified in the cave, and in Gotland in general, during the course of the earliest settlement phase (*Apel, Storå 2017*).

Finds of cores and blades/flakes from the original excavation mostly consist of local flint cores reduced with a rudimentary hard platform technique (see lower part of Figure 4). There is thus a transition from the so-called techno group 2 to 1 in Gotland during the early and middle Mesolithic. This contrasts with the situation in southern Scandinavia where the development goes from techno group 1 to techno group 2 during pre-Boreal and Boreal times (*Sørensen 2006*). From a lithic technology perspective, this is exciting. The blade technique of techno group 2 is more complex than that of techno group 1 and requires more know-how and more sophisticated knapping tools, and thus it is reasonable to ask why this change happened. There are different views about the circumstances that affect and control the degree of technological complexity of hunter-gatherers. A basic premise is that the transmission and passing down of technological knowledge between generations is costly. It must, so to speak, 'pay off', and for hunter-gatherers' this greater profitability may be related to efforts that directly affect food procurement and resource acquisition. Some research has emphasized the importance of mobility for the maintenance of complex techniques. According to this approach, it is advantageous to use more complex technologies, often in the form of compound tools, when moving around the landscape. Conversely, it is advantageous to simplify technologies when you become more resilient and sedentary, and closer to raw materials and food resources (*Binford 1980; Kelly 1995.77ff; Hertell, Tallavaara 2011*). It has also been pointed out that technological complexity co-varies with risk: in situations where the chances of failure are high, there are incentives to invest in more complex technologies that reduce this risk. And vice versa: when there is a low risk of failure, it is more advantageous to 'simplify' technologies (*Torrence 2001; Collard* et al. *2013*).

Several researchers have pointed out that the conditions for the maintenance and dissemination of complex technologies also depends on the relative size of the population and its external network (*Henrich 2004 2010; Riede 2009b; Powell* et al. *2009*). Groups that are large enough and have large external social networks tend to be able to maintain complex technologies, while small groups are at greater risk of losing technological and cultural knowledge over time.

How, then, should we understand the change in the Gotlandic flint and stone tool technology? One possibility is that the smaller size and different quality of the lithic raw material on Gotland may have limited the possibilities in the craft. There are some interesting parallels to this in the osseous craft. The small size of the beach pebbles would then possibly have posed problems as regards to reproducing the technology over time. However, concerning the raw material size and quality, the situation at the island of Bornholm was similar but the technological development was different. On Bornholm for instance, another large island in the Baltic Sea, the only available flint source is *kugleflint*, similar in size and quality to the Gotlandic Ordovician flint. In a study of the development of the stone tool technology of Bornholm it was concluded that the development of the craft over time follows the Maglemosian technological concept, even if the size of the cores, blades and microliths is reduced in the middle and later Maglemosian phases (*Casati, Sørensen 2009.247*). The production of sophisticated blade cores in raw materials of different sizes and lesser quality than South Scandinavian flint is also known from eastern central Sweden, where microblade cores and handle cores were produced in local materials such as porphyry, jasper, ash tuff, different quartzites and even quartz (*Apel* et al. *1996; Guinard 277.280ff*). Thus, it is unlikely that differences in raw material alone would be responsible for the technological changes on Gotland.

Another possibility is that the transition and actually the technological 'simplification' we see over time is due to a combination of the above-mentioned factors. When groups moved to Gotland and came to live there for most of the year, mobility decreased. Given that the Gotland lakes were very rich in resources, consisting of both fish and flora, and large colonies of marine mammals, the conditions for hunting and foraging should have been good. This may have promoted a trend towards simpler technological solutions. It can also be assumed that the first pioneers of this new environment probably had reduced opportunities to maintain external social networks. Perhaps this was also a contributing factor to the change seen in the development of lithic technology?

The bone technology and osseous production on Gotland in light of the finds from Stora Förvar

Descriptions of the types and quantities of osseous implements in the different sections and layers of the cave are found in the original publication by Bror Schnittger and Hanna Rydh. They report a total of 548 bone and antler artefacts from the cave (*Schnittger, Rydh 1940.64*) and provide photographs of a

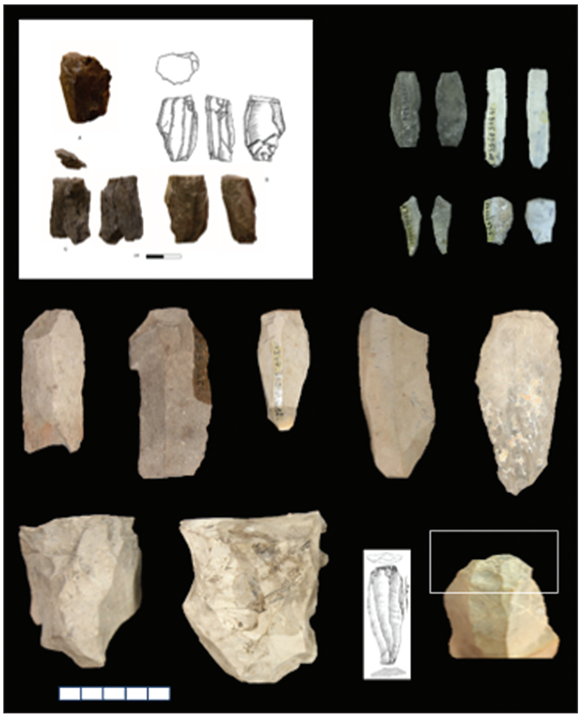

Fig. 4. Flint artefacts from the oldest layers of Stora Förvar. Upper part of picture: two bladecores and blades of the Maglemosian techno group 2. Lower part of picture: blades and blade cores of the Maglemosian techno group 1.

total of 199 and drawings of five different implements. Noteworthy are the high numbers of awls and the small number of formal 'type' artefacts, where the harpoons are the most important ones. The original publication reports 51 'harpoons', two slotted bone points (*fågelpilar*), two arrowheads, one spearhead, 11 daggers, 12 fishing implements, 375 awls (or 'points'), 15 adzes, 20 polishers/flatteners (*glättare*), two saw-toothed artefacts, 15 wild boar teeth (11 knives and two awls), seven animal teeth (mostly pendants and 'a few' awls), three handles, two whistles, 10 needles, four pendants (bone), three bone rings, and an unspecified number of 'worked' bones. This adds up to 535 items, apparently excluding the 13(?) 'worked' pieces needed to reach the reported number of 548.

Schnittger and Rydh also commented upon stratigraphic observations, *i.e.* the commonness of harpoons in section G6. In earlier research a few Gotlandic finds have gained most attention, namely one find of a slotted bone point recovered in the body of a male in a Mesolithic burial at Stora Bjers on Gotland and two other finds from the Stora Förvar cave on Stora Karlsö (see *Apel, Storå 2017*). The two slotted points at Stora Förvar were also recovered in section G, in layers 6 and 7, *i.e.* around 180–210cm down in the stratigraphy of the cave. They have been discussed extensively but here it is enough to note that they do not seem to belong to the oldest pioneer Mesolithic settlement. Schnittger and Rydh (*1940*) noted morphological similarities between some of the harpoons and a spearhead and other finds in the Baltic area. We will not expand further on the discussion on the chronology and typology of various implements here, as the circumstances have changed with the use of exact dating methods.

A sample of bone tools (N=207) recovered in the sections E and F of Stora Förvar, and stored at the Swedish History Museum (SHM) in Stockholm, was analysed in an earlier study (*Apel, Storå 2018*). There we evaluated which species and elements had been chosen as raw materials for the osseous production. Implements made of seal bones were most common in the deeper layers of the cave, while ones made of bones of domestic animals became more common in the upper layers (*Apel, Storå 2018.Tab. 11.2*). This was in good agreement with the earlier observations on the distribution of harpoons and fishhooks, which was taken as an indication that there had been changes in the hunting pattern and the general resource utilization patterns over time at the site (*e.g., Clarke 1946; 1976; Pira 1926*). The observations correlated well also with the general composition of the faunal assemblage through the stratigraphy of the cave, such as the appearance of bones from harp seal and other Atlantic species that indicated a change to more marine conditions and greater salinity in the Baltic Sea (*Clarke 1946; 1976; Pira 1926; Apel, Storå 2018.283-287*).

Osseous implements at Stora Förvar on Stora Karlsö

The data on the osseous implements are presented in the find presentation of the original publication (*Schnittger, Rydh 1940.29-60*). In the present work we have examined the data and recorded information on 572 different osseous elements, Tables 1 and 2. There are some discrepancies between the numbers provided in the find description and the summary (*Schnittger, Rydh 1940.64-67*), but this is not critical to obtain an impression of the assemblage. The implements are described in connection to the finds of each section and layer, and this contains information on the type, dimensions (length), and in many cases the element and/or species that the implement is made of. The information on the artefacts varies but it is most detailed on those that exhibited 'type morphology', such as harpoons, and especially on those that have been photographed. For quite a few items the information includes a comparison and a reference of similarity to a photographed item. This is especially valuable for the interpretation on the many awls that in most cases were made of a seal or pig bone. According to Schnittger and Rydh (*1940.64*), 62 awls were made of seal fibulas, 19 made of metapodials of sheep (?, with one goat?), and 19 of pig fibulas. Bird bone had been used for nine awls, and there are five radii, two ulnae and two humeri. The osteological information on the implements was provided by Adolf Pira, and in some cases by Hjalmar Stolpe (*Schnittger, Rydh 1940.64*). There were 36 bone harpoons and 14 made of antler.

According to our documentation and interpretation of the data in the original publication, we have grouped the implements into 31 categories, as shown in Tables 1 and 2. Most common are awls followed by harpoons, adzes and needles, and then many examples of items represented by only a few specimens. Noteworthy are the concentration of harpoons to the levels 5 and 6, and the more dispersed stratigraphic occurrence of awls. Moreover, implements that belong to the Iron Age or even medieval period are found in the upper parts of the stratigraphy. The stratigraphic distribution of the species used as raw material for the osseous implements show that the domestic animals are concentrated in the upper part of the stratigraphy, while seal bones become more common in the deeper layer, as shown in Table 2. In rough terms, the implements recorded in layers 1–4 belong to the Iron Age, possibly even Bronze Age, or younger. The finds in layers 5–8/9 are from the Late Mesolithic, Neolithic and possibly Bronze Age and, finally, the finds in layer 9/10 and deeper are mainly from the Mesolithic.

If we consider how the osseous implements were shaped and produced, they may be divided into five different categories based on the level of modification of the raw material (Figs. 5 to 7). Again, the observations have been compiled from the original publication and we limit the presentation to levels 5 and deeper (Tab. 3). We here distinguish between the categories *element, long bone (shaft), tool, tooth knife,* and *tooth pendant* (Tab. 3). An additional category is *element/long bone*, where it has not been possible to make a certain judgement of which element had been used as a raw material based on the information available in the original publication (*Schnittger, Rydh 1940*). The division is not exclusive, as different types of implements occur in the same category and similar types of implements are found in different categories. Still, the division illuminates general aspects of the osseous craft and our specific focus is on the layers 9/10 and deeper in order to comment on the Mesolithic osseous craft.

All awls seen in Figure 5.A have been made from fibula and tibia of seal, *i.e. elements* where only the diaphysis has been modified, shaped, and partly polished, and the tip sharpened. The epiphyseal end of the awls is most often modified only slightly, and it is thus possible to determine from which specific element the implement was made from. Therefore, the items in this category are skeletal elements for which most often only the working edge – or tip – has been modified.

Artefact type	**1**	**2**	**3**	**4**	**1-4**	**4-5**	**5**	**6**	**7**	**7-8**	**8**	**9**	**10**	**11**	**12**	**13**	**11-12**	**12-14**	**14-15**	**nd**	**Total**
Finger ring					3																3
Gaming piece	1																				1
Comb	4																				4
Whorl		1																			1
Skate	1			1																	2
Harpoon	1			1			15	21	4		1	1		1			1			1	47
Barbed point/harpoon												1	1								2
Notched point	1							2					1								4
Arrowhead/point												1									1
Slotted bone point								1	1												2
Point							1				1			2	1						5
Point/awl													3		1		1				5
Awl	1	9	11	25	1		41	58	44	2	32	46	33	23	17	4	11	1	3	2	364
Awl?			1	1																	2
Dagger/awl						1	1	1	1					1							5
Adze			2				1	1	2		2	1	5			1					15
Adze+awl												3									3
Needle	1	1						3	1		1		2				2				11
Double needle/awl/hook								3			1							2			6
Boar tusk							1	7			1	3	1				1			1	15
Bone tube									2												2
Fishhook							3					1	1				1				6
Tool							2	7	1		2		1	1	1		3				18
Tool?		1	1		2	2	1				1		4	1	1			1			15
Pendant																	1				1
Pendant?							1		1												2
Tooth pendant		1					1					2	2					2			8
Tube/bead								1													1
Tube?			1																		1
Worked bone	1	1					5	3	4			3	1		1						19
Raw material?			1																		1
Total	**11**	**14**	**17**	**28**	**6**	**3**	**73**	**108**	**61**	**2**	**42**	**62**	**55**	**29**	**22**	**5**	**21**	**6**	**3**	**4**	**572**

Tab. 1. Identified artefact types among bone tools in different layers of Stora Karlsö according to the original publication (*Schnittger, Rydh 1940.Ch. 5*);* NISP *number of identified specimens. There may be some discrepancies in the data due to problems of interpretation.

The awls/points in Figure 6.E have all been made from long bone (shafts). It is still possible to determine that it was made from a long bone but not from which specific element. The long bones have often been split or splintered. They often exhibit fresh fractures and the working edge has been shaped and often carefully polished. Occasionally both ends have been shaped and modified. The category is important as it is often possible to determine whether the implement was made from an element of seal or not, which is of interest at Stora Förvar. Bones of terrestrial mammals probably had to be brought to Gotland, or else the implements were brought there. Considering the 'lack' of waste products in the cave the latter alternative may be more plausible. The awl in Figure 7.C was made from a long bone of a large mammal (ungulate).

The barbed item in Figure 5.C represents a tool, where most of the surface has been modified. On tools it is (most often) possible to determine only whether it has been made of bone or antler and not which specific element has been used. The needle in Figure 6.A and the awl/point of antler in Figure 7.A, though it was recovered in G7, may also be considered a tools, as the whole surface of each item has been modified and shaped.

Two types of implements made from teeth have been found at Stora Förvar. The first category comprises wild boar tusks where the tip of the tooth exhibits modifications and traces of wear. The identification as wild boar is reasonable, but it has not been possible to assess this in detail. There may be a danger that some of the (wild boar) implements are later (Neolithic) intrusions in the older layers, and thus may originate from domestic pigs. The rather homogeneous pattern of modification of the tip of the teeth suggest they were produced in a similar craft context, probably chronologically restricted to the Mesolithic. Schnittger and Rydh (*1940*) labelled these items as knives, and the term has been retained here even if the implements were probably used in various ways. Finally, a few teeth, most often seal canines, that had been used as pendants were identified.

The osseous craft on Stora Karlsö

The two traditions or techno groups of lithic blade production mentioned above are also linked to differences in osseous production (*Bergsvik, David 2014; David, Kjällquist 2018; Gummesson 2018; Gummesson* et al. *2019*). It is thus possible to relate the osseous craft and bone technology found on Gotland, and especially that of Stora Förvar, to that found on mainland sites. This is not the place for an extensive review, but a comparison to recent studies of osseous craft and technology on three Mesolithic sites in Sweden is sufficient to contextualize the Gotlandic finds and craft. There are a few sites from the

	1	2	3	4	1-4	4-5	5	6	7	7-8	8	9	10	11	12	13	11-12	12-14	14-15	nd	Total
Grey seal													1								1
Ringed seal									1				5	1	1		1			1	10
Seal		2	2	1		2	4	22	12		6	8	15	12	2	1	1	3	3		96
Elk	1																				1
Cervid			1				1	9			1										12
Cattle					1																1
Horse	1		1																		2
Large mammal			2	1	1			1			1	1	1	2							10
Pig			1				2	13	1		2	4	1		1		3			2	30
Pig?								3													3
Sheep/goat			4	6			5	1	2		1	2									21
Ungulate		1				1		1					2								5
Red fox				1																	1
Hare									1			2									3
Small mammal											1	1									2
Bird			2	3			1	3	11		9	3	1		1		2	1			37
Eagle															1						1
Mammal	9	11	4	13	4		51	47	26	2	19	37	23	10	9	2	13	2		1	283
Unidentified				3			9	8	7		2	4	6	4	7	2	1				53
Total	**11**	**14**	**17**	**28**	**6**	**3**	**73**	**108**	**61**	**2**	**42**	**62**	**55**	**29**	**22**	**5**	**21**	**6**	**3**	**4**	**572**

Tab. 2. Identified species among the artefacts in different layers of Stora Karlsö according to the original publication (**Schnittger, Rydh 1940*****);* NISP *number of identified specimens. There may be some discrepancies in the data due to problems of interpretation as some, but not all, identifications were possible to verify based on the text and the photographs.***

Modification/tool type	4-5	5	6	7	7-8	8	9	10	11	12	13	11-12	12-14	14-15	Total
Element															
Harpoon		1	2												3
Adze		1		1				3							5
Dagger/awl	1		1	1											3
Awl		6	29	17		7	13	15	13	7	2	5	1	2	117
Tool		1	4						1						6
Tool?	2							2							4
Bone tube/handle?				2											2
Worked bone		1													1
Long bone shaft m.															
Harpoon		2													2
Adze			1	1		2	1	2			1				8
Adze+awl							3								3
Dagger/awl		1							1						2
Fishhook		3					1					1			5
Awl		25	17	14		8	8	12	5	5		6		1	101
Double needle/awl/hook			3			1							2		6
Point						1			1						2
Point/awl								3				1			4
Needle			1			1		2				2			6
Tool			1							1		2			4
Tool?		1				1		2	1	1			1		7
Pendant												1			1
Pendant?		1		1											2
Element/Long bone															
Barbed point/harpoon							1								1
Boar tusk		1													1
Awl		10	12	12	2	17	25	6	5	5	2				96
Point		1							1						2
Point/awl										1					1
Needle			2	1											3
Tool			2	1		2		1				1			7
Tube/bead			1												1
Worked bone		4	3	4			3	1		1					16
Tool															
Harpoon		12	19	4		1	1		1			1			39
Barbed point/harpoon								1							1
Notched point			2					1							3
Slotted bone point			1	1											2
Arrowhead/point							1								1
Fishhook								1							1
Awl				1											1
Point										1					1
Tool		1													1
Tooth knife															
Boar tusk			7			1	3	1				1			13
Tooth pendant															
Tooth pendant		1					2	2					2		7
Total	3	73	108	61	2	42	62	55	29	22	5	21	6	3	492

Tab. 3. Level of modification of osseous tools in different layers (5–15) at Stora Förvar according to information in the original publication (*Schnittger, Rydh 1940*); *NISP *number of identified specimens. Definition of the categories is found in the text.

Late Boreal and Early Atlantic periods with preserved finds of osseous craft, such as Ringsjöholm in Scania (*Gummesson* et al. *2019*), Sunnansund in Blekinge (*David, Kjällquist 2018*), and Strandvägen in Östergötland (*Gummesson 2018; Gummesson* et al. *2019*). The first two of these sites are dated to around 9500–8000 BP, *i.e.* the time when the pioneer settlement had reached Gotland while Strandvägen is slightly younger, *c.* 8000-6500 BP, *i.e.* the period during the hiatus of the settlements on Gotland. The bone tools found at Stora Karlsö illuminate aspects of the utilization of animal resources, namely the specific choices of raw material for osseous production.

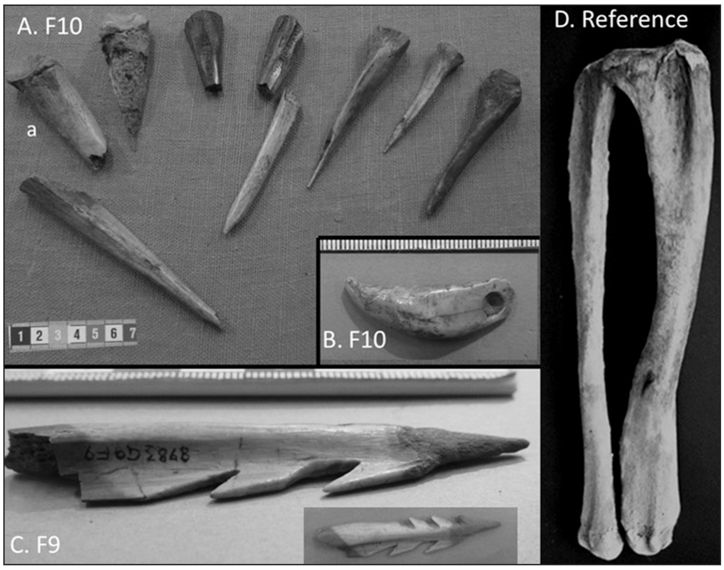

Fig. 5. **A** ***nine awls recovered in section F and layer 10. All made of seal fibulas except the one labelled*** **a** ***which was made of a tibia.*** **B** ***tooth pendant made of canine from grey seal from section F, layer 10.*** **C** ***tip of bilaterally barbed point (harpoon) recovered in section F, layer 9. It was probably made from a grey seal tibia.*** **D** ***crural bone (tibia and fibula) of a seal, modern reference. The long and slender diaphysis of the two elements were the most important raw material for osseous production at Stora Förvar.***

When comparing the assemblage of osseous artefacts from Stora Karlsö to those on the mainland settlements it is immediately evident how different, in many aspects, the bone technology was on Gotland. The finds from the two sections, E and F, are here compared to the other assemblages. These finds were studied at SHM, with the faunal remains (from section F) the focus of osteological analysis. First, when examining the raw materials used for the osseous craft in the oldest layers of the cave, the difference in availability of prey animals and, thus, suitable raw material for tool production is reflected (Tab. 4). The importance of red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*), but also wild boar (*Sus scrofa*) on Mesolithic sites is evident as bones from these are the most common on Ringsjön and Sunnansund as raw materials. In addition, on the more northerly locat-

Fig. 6. **A** ***needle made from a long bone with a completely polished surface that hinders an identification of the element it was made from. Recovered in F12.*** **B** ***awl/needle made from fibula of an adult seal where the tip is crudely shaped. The tool has probably been reshaped. Recovered in F8.*** **C** ***awl made of a tibia of a seal where the tip is crudely shaped and a large surface with cancellous bone visible. Recovered in F9.*** **D** ***awl made of tibia of an adult ringed seal. The tip is well polished. Note the damaged tip. Recovered in F9.*** **E** ***awls/points made from long bones (shafts) that have been split or splintered. The bones exhibit fresh fractures and the working edge has been shaped and often carefully polished. Occasionally both ends have been shaped and modified. Three of the implements have been made of long bones of terrestrial mammals, not seals. The implement labelled "a" is from a bird. Recovered in E9.*** **F** ***awls, made of the distal part of the tibia of a hare (a) and from the tibia of a ringed seal (b). Recovered in F8.***

ed Strandvägen, the skeletal elements of Elk (*Alces alces*) were also an important raw material. The species that provided skeletal elements for tools production at Stora Förvar were seals, but some finds of bones of large ungulates, cervids and possibly wild boar also occur. The occurrence of sheep/goats among the Mesolithic finds is an obvious recent intrusion (see *Apel, Storå 2018* for more details). The layers F9-F8 mark a transitional horizon between the Early and Middle Mesolithic and Late Mesolithic/Neolithic finds. Note the appearance of harpoons, fishhooks, and boar tusk implements that most likely mainly belong to the chronologically younger finds.

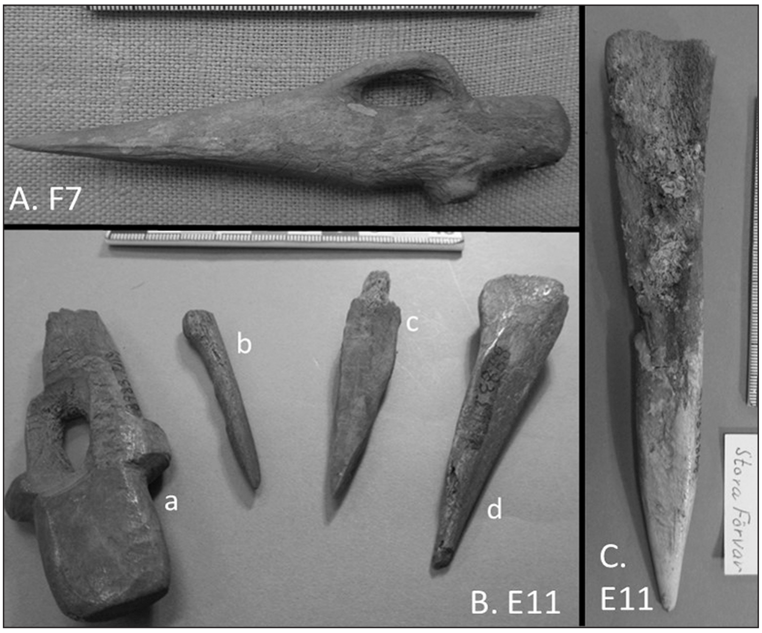

Fig. 7. A ***awl (point?) made of antler recovered in F7.*** B ***the base of a similar implement as in*** A ***(***a***), unknown type, possibly a shaft part from a fishhook or needle/awl (***b***). Two awls made from the tibia (***c***) and fibula (***d***) of a seal. Note the polish and damaged working edge of*** d***. The implement was possibly discarded as it became too short during use. All items found in E11.*** C ***large implement (awl/point) made of the long bone of a large mammal, not seal. The working end is polished and shaped. Recovered in E11.***

The difference in osseous raw material availability may be seen as a parallel to the different availability of (good) lithic raw material that the pioneer settlements also faced but evidently adapted to. It seems that the craft to a high degree considered the prerequisites of the raw material. Some level of simplification is evident, in a similar manner to that seen for lithic technology. The osseous craft produced a rather specific and limited set of tools at Stora Förvar. At the same time, however, we might consider this a specialization.

The lack of large ungulates on Gotland forced the pioneers to select seal bones as a raw material for osseous production. The skeletal elements are not suitable as raw material in the same manner as certain elements of ungulates such as metapodia, radii and to some extent also femur and humerus or antler of cervids. Still, seal bones were the most common raw material, which apparently put some strain and limitations to the craft. Considering the morphology of seal bones, it is actually only the tibia and fibula, which in seals are proximally fused to form the crural bone, and the ribs, that are long and slender. Most other elements are small, irregular and often with curved outlines which make them difficult to use. Teeth have commonly been extracted from the seal jaws, especially the canine teeth that were used as pendants or possibly dress ornaments. We may note that seals are represented with one implement only on Sunnansund, a tooth pendant. Bird bones were used more frequently at Stora Förvar than at the other sites. That seems to be a local adaptation, but may also be a preference to utilize the often hard but thinner bone structure of bird bones (Figs. 5–7). Bones of mountain hare exhibit similar properties, as do those of many small-sized mammals. The finds of tools and artefacts made of antler and (long) bones of large ungulates in the cave most probably represent imported tools, or tools made from raw material that was imported to Gotland.

The frequency of different tools is markedly different on the sites (Tab. 5). Slotted items are the most common category on Ringsjöholm (11%) and Sunnansund (33%) while barbed points are most common at Strandvägen (30%), followed by plain bone points (12%). This difference has been discussed at some length (see *Gummesson* et al. *2018* and references therein), but for Stora Karlsö the almost complete absence of these categories of tools is of interest. Awls are the most common category at Stora Förvar, both in the oldest Mesolithic layers (78%) and the Late Mesolithic/Neolithic (66%) layers among the analysed osseous implements at SHM. The frequency of awls is 70% in all Mesolithic layers according to the data in the original publication (*Schnittger, Rydh 1940*).

Pendants are more common in the assemblages from Ringsjöholm (8%) and Sunnansund (12%) than at Stora Förvar (3%) and Strandvägen (1%). Ringsjöholm exhibits slightly more varied material than Sunnansund, but this may be related to the difference in sample size. Strandvägen has the most varied and rich material of osseous implements, which also may be related to the larger sample size. However, the difference in the composition of the material at Strandvägen is still noteworthy, as many elements seen on the older sites have been retained here (*Gummesson* et al. *2018*), while they disappeared on the Gotlandic sites.

The assemblage of osseous tools at Stora Förvar has to be considered as less variable than those on the other three sites. This is seen in the more limited number of species used as a source for raw materials and also in the smaller variability of tool types. Finally, it may be noted that the assemblage from Stora Förvar lacks waste products. This, however, is not completely true, as a few of the artefacts appear to be preforms while other implements have obviously been modified and re-shaped, possibly on site. Also, there is a category of items classified as 'worked pieces' by Schnittger and Rydh (*1940.64*), *i.e.* smaller fragments with traces of polishing or other marks from the production. Biased recovery may probably have contributed to a certain loss of small fragments and, thus, presumably waste products, but it is not only the smallest waste products that are lacking in the assemblage. Waste products were also absent among the finds from the 2013 excavations where water sieving was employed. It may be concluded that the osseous production here was rather different than at the other sites. As seal bones are not well suited as raw material for tool production the pioneers had locally different availability and access to good bone raw material for tool production, in contrast to the situation on the settlements on the mainland. We need to consider different reasons for the differences, as there was surely some degree of shortage with regard to local availability of raw materials, *e.g.,* elements of ungulates, but at the same time maybe the hunting of seals did not require the larger implements and points that have been identified on the mainland sites. This issue cannot be resolved here, but we acknowledge that there are no simple explanations to this.

	Ringsjöholm	Sunnansund	Stora Förvar, E/F9-13	Stora Förvar, E/F5-8	Stora Förvar, 9–13 (1940)	Strandvägen
Alces alces	2					35
Bos primigenius	1					
Capreolus capreolus	12	7(9)				30
Cervidae	9	5	2	3		13
Cervus elaphus	26	9(11)				281
Bos taurus				2		
Ovis aries/Capra hircus			2	4	2	
Sus scrofa	11	2	3	4	9	24
Large ungulate/mammal	6	38(46) +12	16	14	4	381
Ungulate	3				2	
Ursus arctos	2					1
Felis silvestris	1					
Meles meles		1				
Lutra lutra		1				
Martes martes	3					
Small carnivore	4					
Carnivora	2					
Halichoerus grypus		1	11	1	1	
Phoca hispida			19	6	8	
Phoca sp.			38	6	42	
Castor fiber						1
Lepus timidus			3	1	2	
Aves			12	9	8	11
Unidentified mammal	234	1	9	11	119	691
Total	**316**	**70(89)**	**115**	**61**	**197**	**1468**

Tab. 4. Identified species used as sources of skeletal elements for osseous craft on different sites. Data for Ringsjöholm and Strandvägen is found in Gummesson **et al. *(*2019.Tab. 3*), for Sunnansund in David and Kjällquist (*2018.Appendix 9.1*), and for Stora Förvar, 9–13 (1940) in Schnittger and Rydh (*1940*). The finds from Stora Förvar E/F were analysed at SHM in Stockholm.***

A new interpretation of the earliest Gotland settlements

In previous research, the rich occurrence of marine mammal bones (seals) in the cultural layers of the Mesolithic settlements was interpreted as reflecting the main driver of the colonization of Gotland (*Pira 1926; Schnittger, Rydh 1940; Clark 1976; Österholm 1989; Lindqvist, Possnert 1999; Wallin, Sten 2007; Andersson 2016*). This is not surprising considering that over 1000kg of seal bones have been collected in the Mesolithic layers from Stora Förvar, and bones of seals also dominate the other faunal assemblages on Mesolithic sites (*Apel, Storå 2018*). One important exception to this is Ericson's study which highlights the importance of fish for the settlements, even if this mostly concerns the Atlantic (*i.e.* Late Mesolithic) and Subboreal (Neolithic) conditions and is also related to taphonomy, mainly the preservation bias favouring seal bones (*Ericson 1989*). An early study that also warrants attention is that of Welinder, who emphasized the importance of the lake environments and thus fish resources for the Mesolithic settlements in South Scandinavia (*Welinder 1978*). Other important studies focus attention on the recovery bias, especially for Gotland (*Johansson, Larje 1993; Lindqvist 1997; Olson, Walther 2007*). More recent research has shown that freshwater fish were an important resource for Mesolithic settlements in many regions of Northern Eu-

Type of implement	Ringsjöholm	Sunnansund	Stora Förvar, E/F10-13	Stora Förvar, E/F5-9	Stora Förvar, 9–13 (1940)	Strandvägen
Heavy-duty tools		2				
Barbed point	6			2	2	446
Harpoon head	1	1	5	8	3	14
Slotted bone point	34	14				43
Plain bone point	5					180
Arrowhead					1	8
Spearhead			1			16
Notched point				1	1	
Bone point, unspec.	17		1		3	
Needle/pin	15		3	2	4	35
Slotted dagger						8
Ulna dagger					1	1
Awl	7	4	90	40	137	71
Double awl			2	2	3	
Chisel		6				53
Knife		3				5
Wedge						1
Navette						7
Fishhook	1		1	1	3	1
Gorge						3
Pressure flaker	8					33
Antler axe/adze/mattock	3					10
Bone adze	1		5	1	7	
Antler club						6
Club (bone)	1					
Antler shaft						4
Antler sleeve						3
Decorated antler object						6
Stopper/cork						3
Knife/scraper, boar tusk	2				5	7
Enamel tool	1		2			13
Beads/pearls/pendant	26	5			5	13
Handle-like		2				
Unidentified antler object	14		2			31
Unidentified	174	6	3	4	22	447
Osseous implements, total	**316**	**43**	**115**	**61**	**197**	**1468**
Waste (+unfinished)	977	34				2185

Tab. 5. Identified types of osseous implements on different sites. Data for Ringsjöholm and Strandvägen is found in Gummesson **et al. *(*2019.Tabs. 1–2*) for Sunnansund in David and Kjällquist (*2018.Appendix 9.1*), and for Stora Förvar, 9–13 (1940) in Schnittger and Rydh (*1940*). The finds from Stora Förvar E/F were analysed at SHM in Stockholm.***

rope. In Scandinavia, this is evident both in light of the composition of the site refuse faunas (see *Boethius 2017; Boethius, Ahlström 2018*) and analyses of stable isotopes of human remains (*Eriksson* et al. *2018*). The pioneers of Gotland, with a probable origin in mainland and coastal environments, should have been well aware of these resources, but – as mentioned above – the importance of fish was not the focus of the early research. However, the island of Gotland was actually rich in lake environments (see *Apel, Storå 2018*). In light of the new knowledge about Mesolithic subsistence patterns and adaptive dynamics, we wanted to scrutinize the interpretations on the subsistence of the pioneer settlements on Gotland. In earlier publications we have focused attention on prey choice in the exploitation of seals (*Apel, Storå 2018*), the importance of freshwater fish for the pioneer settlements (*Apel, Storå 2018; Boethius* et al. *2017*), and the general chronology and character of the demographic development (*Apel* et al. *2017*).

Seal hunting

During all periods of the Mesolithic, seal hunting on Gotland was focused mainly on the youngest seals of both grey seal (*Halichoerus grypus*) and ringed seal (*Phoca hispida*) that were hunted during late winter and early spring, but initially also later in the year. The hunting season at Stora Karlsö initially appears to have been more than six months long, but was then shortened to around three months (*Apel, Storå 2018*). As the hunting season became shorter, grey seals of smaller body size were hunted, which in turn resulted in a smaller yield of the hunt (Fig. 5). If the breeding season of the grey seal and ringed seal was the same as today, hunting probably started on the ice, but perhaps there were also colonies of grey seals on the beaches at Stora Karlsö and other places on Gotland that could be hunted 'from land'. The ringed seal, on the other hand, is more solitary, and judging from the age of the seals the hunters searched for breeding lairs and/or breathing holes in the ice. The apparent prevalence of fast ice, which is necessary for ringed seals, this far south in the Baltic Sea differs markedly from the situation today, when the species usually occurs in the northern parts of the Baltic basin. The seasonality patterns, prey choices, as well as the general chronological changes observed show that the seal hunting patterns were dynamic and unequivocally of significant importance on Gotland throughout the Mesolithic.

The hunting patterns for seals underwent changes through time, and the species distribution sheds some light on the stratigraphic integrity in the cave (*Landeschi* et al. *2018*). Of interest here is the appearance of the harp seal, which entered the Baltic Sea around 6000 BP, approximately when the hiatus in the cave ends (*Bennike* et al. *2008; Storå, Ericson 2004*). Bones of harp seals appear in the sections and layers B6, E7, F9, G7, H7, and I5 (*Apel, Storå 2018; Pira 1929*). This roughly coincides with the appearance of bone harpoons and fishhooks and larger quantities of Pitted Ware culture pottery (*Landeschi* et al. *2018*). Bones of domesticated animals become more common in the uppermost layers, which date to the Iron Age and Historical period (*Landeschi* et al. *2018*). Some finds of sheep and other domestic animals are found as deep as G8 (*Lindqvist, Possnert 1997*). Thus, the oldest Mesolithic finds are found in layers deeper than 10 while late Mesolithic/Neolithic finds appear approximately in layer 9. It is important to note that in the inner parts of the cave pottery and other 'young' finds are found even in the bottom layers (I7 and H7).

Importance of fish

The site refuse faunas of the oldest Gotlandic Mesolithic settlement sites show a large number of fish species such as various types of carp, pike, burbot and salmon (*Knape, Ericson 1988; Lindqvist, Possnert 1999; Boethius* et al. *2017*). Due to the recovery techniques used, the species representations are difficult to evaluate (see *Lindqvist 1997*). It is evident that the pioneers also collected various types of molluscs and hazelnuts (*Munthe, Hansson 1930*), in addition to hunting of seals (*Pira 1926; Ericson 1989; Apel, Storå 2018*), hares and foxes (*Lindqvist, Possnert 1999; Ahlgren* et al. *2016*). Ungulates, a common prey on the mainland, were absent on Gotland. There are, however, several reasons to believe that freshwater fish played a major role for the first pioneers, and we have suggested that in fact it may have been the many shallow lakes in northern Gotland that attracted the first pioneers to the island (*Apel, Storå 2017; Boethius* et al. *2017*). The earliest settlement appeared on Gotland in a time of hot summers but cold winters, and the general trend for the climate was that it became warmer. The pioneer settlement came to an environment that was different from that of the mainland, and important prey animals were absent. The fact that Gotland is an island that has not been in direct contact with the mainland most probably characterized the local flora and fauna. The surrounding water was a barrier for the dispersal of many species. However, the environments with the lakes were familiar and perhaps much more important than previously thought. The specific focus on seal hunting may be seen as a new element, but this element was incorporated into a larger adaptive strategy. The oldest settlements on Gotland are, admittedly, often located on the coast, but it is important to note that they are also located in direct connection with lake environments. This is also the case on the mainland (*e.g., Boethius 2018*).

Assessing the significance of fish based on bone finds has been challenging. The finds of the older excavations and surveys are not reliable, mainly because water sieving or fine-mesh sieving were not adopted, a problem not unique to Gotland (for a discussion see *Boethius 2016; Enghoff 2007; Johansson, Larje 1993; Lindqvist 1997; Olson, Walther 2007; Segerberg 1999*). This has been noted before (*Knape, Ericson 1988*), but based on the results of the 2013 survey at Stora Förvar, and of the recent excavations at Gisslause, it is evident that fish bones are indeed are very common in Mesolithic Gotland settlements where water sieving has been used (*Apel, Vala 2013; Apel* et al. *2015; Boethius* et al. *2017; Apel, Storå 2018*). A more indirect but still important indication of the importance of fish in the diet is the fact that bones from the Mesolithic pioneers exhibit a reservoir effect that can be linked to a large intake of freshwater fish (*Boethius* et al. *2017*). Fishing implements are rare on Gotlandic sites, but in southern Scandinavia discoveries of the net sinks, bright spots, shoals and fermentation contexts from the Boreal time further show the significant importance of fishing for these communities (*Andersen 1978; Boethius 2016; Hammarstrand* et al. *2008; Hansson* et al. *2018; Johansson 2006*).

Vegetable resources

Hazelnuts have a high energy value and were evidently an important staple food during the early Holocene in northern Europe (*Holst 2010.2871*), and also appear on Gotlandic Mesolithic sites. However, vegetables (which were also used for purposes other than food) are almost invisible in the archaeological record. It has been suggested that the rapid spread of hazel in Northern Europe during early Boreal time may be due to the fact that humans brought it with them. As hazel appears earlier in the eastern Danish islands than in western Denmark, Iversen suggested that it might have been transported by people in boats along the Oder and Weichsel Rivers and further up to the Dana River in the present Great Belt (*Iversen 1973.62*). However, it has been pointed out that there are source-critical problems that must be resolved before such an interpretation can be confirmed (*Björkman 2007.70*). Regardless, this hypothesis is particularly interesting for Gotland, partly because it is an island, and partly because it seems that certain wild animals were taken to the island by humans both during the Mesolithic and Neolithic, *e.g.*, the mountain hare (*Lepus timidus*) (*Ahlgren* et al. *2017*), hedgehog (*Erinaceaus europaeus*) (*Fraser* et al. *2012*) and possibly also pig (*Sus scrofa*) (*Jonsson 1986*).

It is a tempting thought that the first pioneers would have brought hazelnuts and other nuts to create nurtured hazel environments near the places of the settlements. However, perhaps a more sensible interpretation, which does not exclude the role of humans, is that the hazel had already been spread to the island by birds, and that the pioneers favoured it by clearing areas near the settlements and tending the bushes. It has been suggested that hazelnut was favoured by contemporary hunter-gatherers in southern Scandinavia (*Regnell, Ekblom 2001.266*). It was not only an important food, but could also be used for trapping devices and arrow shafts.

Another edible plant that was abundant in the many shallow, overgrown Gotland lakes during Boreal times is the bulrush (*Typha*). Seeds have been found on millstones from a 25 000-year-old site in Bilancino near Florence, Italy (*Aranguren* et al. *2015*), which shows that European hunter-gatherers knew of and used the plant quite early. It is productive and can be eaten fresh (the young stalk), while the seed capsule and roots can also be ground into flour, boiled or roasted, and may very well have been used as a carbohydrate source. According to calculations made by the Swedish Defence Force in the 1980s, roots of phragmites could support large parts of the Swedish population in the event of an emergency (*Persson 1999.175*), and it has been pointed out that phragmites and clover (*Trifolium*) may have been used as food during the Mesolithic period (*Larsson 1978.186*).

The shallow lakes of northern Gotland during Boreal times should have had large populations of yellow water-lily (*Nuphar lutea*) that could have been used by the pioneers. Seeds of yellow water-lily have been collected at contemporaneous settlements at Holmegaard's bog in Denmark (*Broholm 1931.19*) and are also known from recent excavations of a Mesolithic site in Ageröd, southern Sweden (*Boethius* et al. *2020*). Yellow water-lily, for example, was the most important traditional food for the Klamath Indians in Oregon, which fed on fishing, hunting and, above all, on the collection of yellow water-lily in shallow, overgrown lakes from stock boats (*Coville 1902*). There are archaeological indications that wild apples were collected at Boreal settlements around Ringsjön in Skåne, and it is likely that raspberries and other berries also were included in the Boreal diet (oral information from Arne Sjöström, Department of Archaeology, and the History of Antiquity, Lund University, see *Boethius* et al. *2020*).

Changing environments and adaptive dynamics on Mesolithic Gotland

Seal bones also occur in Mesolithic site refuse faunas on the coasts of the Baltic Sea, but these exhibit a more varied species representation including terrestrial species, and especially different ungulates (see *Magnell 2006; Magnell* et al. *2020*), with these species missing on Gotland. Thus, the subsistence base on Gotland – or actually the terrestrial fauna – probably lacked important elements of variation and diversity that could have affected the Mesolithic settlements, not necessarily in deterministic terms but still affecting regional and specific adaptive dynamics. It is evident from the zooarchaeological analyses of the site refuse faunas of the Gotlandic Mesolithic sites that even if seal bones do indeed occur in high numbers, other resources had to be exploited. Moreover, the Gotlandic settlement and adaptive strategies might have been sensitive and had to be responsive to the recurrent changes in environmental conditions we know took place. The changes in salinity of the Baltic Sea and general climatic trends of the period may actually have been especially important for the seals.

The predictable boreal climate changed drastically about 8200 years ago in connection with a rapid cooling that occurred in the northern hemisphere and then lasted for hundreds of years (*Manninen 2014*). This cold period affected population development and the place of residence in much of northern Europe, Denmark and Sweden (*Riede 2009a*). At Gotland, the temperature decrease is seen in a 10 000-year temperature curve above the average temperature in July in the lake Tingstäde Träsk (*Mörner, Wallin 1977*), and also as a marked reduction in pine and increase in birch in the pollen diagrams at the transition between pollen zones VI and VII (Boreal/Atlantic period) (*Påhlsson 1977*). These changes have previously been interpreted as a result of the Ancylus transgression (*Österholm 1989.14*), but since it reached its maximum already in pre-Boreal time it is more reasonable that they should be associated with the 8200 BP cold event. In Blekinge and Estonia, geologists have documented sediments from this period suggesting high cyclonic activity in the Baltic Sea area, with severe storms as a result (*Berglund* et al. *2004; Veski* et al. *2004*). The cold event at 8200 BP probably affected the Mesolithic settlements on Gotland.

When the effect of the cold period subsided, the temperature rose rapidly, and about 8000 years ago lime and ash appear in the Gotland pollen diagrams (*Påhlsson 1977; Mörner, Wallin 1977*). The warmer and more humid climate during the Atlantic period lead to the development establishment of a dense oak mixed forest on the island. However, the rise in temperature created a rapid melting of ice at the poles and a rise in sea levels, and in the Baltic Sea this lead to the first Littorina transgression reaching its maximum 7600 years ago (*Risberg* et al. *2007*). The transgression raised the sea level by over 4m and Mesolithic settlements close to the shoreline on Gotland, such as Gisslause, Svalings and Strå, were flooded and overlain by thick layers of limestone (*Munthe 1940*). The transgression did not really reach the Stora Förvar estuary, which is today about 21m asl (*Schnittger, Rydh 1940.19*), but the sea level certainly affected the conditions for hunting marine mammals on the beach below the cave. In addition, the beach vegetation changed. However, the changes should not have significantly affected the conditions of the seal populations, although the higher salinity and thus higher productivity should have benefited them.

As indicated by the data presented above, it was not only the hunting of seals that determined the settlement and activity patterns during the Mesolithic in Gotland (see *Ericson 1989*). We also see traces of other activities that fall into other seasons, such as fishing, exploitation of birds and not least hazelnut shells. The chronologically earlier settlements on Gotland were always located close to lakes, even though they had a coastal location. Probably the most important consequence of the sea level rise was that the coastal lakes were flooded with salt water. With this, the environments in which the oldest settlements were located changed. The settlements on the main Gotland island that have been radiocarbon dated to the Atlantic era, *i.e.* Svalings, Visborgs Kungsladugård and Norrbys, are now facing the salty Littorina Sea, but without close contact with lakes. Activity on Stora Karlsö seems to be slowing down, although the location of the site was different from those of the other settlements. The seal hunting patterns are also changed. Up to 50% of the hunted seals now consist of ringed seals, a species that is more difficult to hunt and is also smaller than the grey seal. At Norrbys, the discovery of one of the earliest finds of a harpoon suggests that seal hunting had become more sophisticated by the early Atlantic period, as harpoons are missing from the chronologically earlier Late Boreal settlements. We may note that the production of harpoons would have been difficult using seal bones as raw material. One harpoon recovered in G7 at Stora Förvar is made of the mandibula of a grey seal (*Schnittger, Rydh 1940.Pl I.3*). Seals had been hunted with other techniques during the older period, and perhaps they were clubbed on the ice or beaches. Active hunting in open water does not seem to have been common (*Apel, Storå 2018*).

The image of the first pioneer settlements on Gotland is a complex one. Hunter-gatherers are often defined by the fact that, unlike farmers, they do not produce their own food but instead survive by hunting, foraging and collecting existing species in the environment. The first pioneers seem to defy this image. By transporting hares and perhaps even foxes to Gotland and thus creating populations that could be hunted and possibly also by nurturing the growth of hazel, they may have mastered and changed the environment to their own advantage. The hares and foxes would also have produced raw material for the osseous craft, in addition to furs and meat. The presence of eagle bones at Gisslause (*Munthe, Hansson 1930; Apel, Vala 2013*) and Stora Förvar (*Lindqvist, Possnert 1999*) is an indication that the main competitor for the hares may have been guarded, but here also the bones of the birds were apparently desired for bone craft and, possibly, more so than on mainland sites.

The often-emphasized importance of seal hunting needs to be scrutinized even further. To this we can add the large-scale consumption of inland fish, which in itself should have been based on mass fishing with advanced techniques in the growing shallow lakes of northern Gotland and also in their outlets to the Ancylus Lake. This important environment was probably greatly influenced by the changes in the natural conditions, and this may be the main cause of the decline in activities we can note during the late Mesolithic on Gotland. The increasing temperatures should have given people better opportunities in the interior of the island, but a more marked expansion to these areas apparently occurred later than was previously believed. The so-called 'axe' settlements that are situated in the interior parts and were earlier interpreted as being from the Late Mesolithic seem to date either to the Early Atlantic era (*e.g.,* Norrbys) or later to the Mesolithic/Neolithic (*e.g.*, Ajvide and Nasume).

A source critical factor that needs consideration is that few of these sites have been archaeologically investigated and dated. The hiatus in settlement activities also needs further attention, but it is evident that the earlier development halted. Of importance is that there are no secure finds of Ertebölle pottery on Gotland (dated to *c*. 7300-6000 BP), which reinforces the impression of more sporadic visits to Gotland in the Late Mesolithic (Atlantic period) than in earlier times, but also after *c*. 6000 BP. Perhaps the 8200 BP cold event and subsequent transgression contributed to a fairly extensive demographic restructuring in the Scandinavian hunter-gatherer groups, which would probably have also affected the coastal groups. If so, it is not difficult to imagine that the remaining human groups in Scandinavia concentrated in the (richer) mainland environments with good communication routes – but perhaps also with lakes with fish resources that were not affected by the impact of the Litorina Sea. The Strandvägen site in Östergötland may be one such example. The more peripheral environments, such as Gotland, which during the most productive phase of Late Boreal time offered favourable conditions with rich lakes and large seal colonies, seem to have been abandoned or used only sporadically for a long period of up to 2000 years. After this, what had once been important on the islands no longer seems to have attracted people there.

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