Neolithic Fisheries

Osteoarchaeology of Fish Remains in the Baltic Sea Region

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Abstract: Fisheries in the Neolithic period targeted the same fish species present in the Baltic Sea today. The variety of species found at the archaeological sites indicates the exploitation of local and regional ecosystems. Inner, middle, outer archipelago, or an open sea environment constitutes the surroundings of the sites in the present study. The focus of the fisheries often varies from site to site.

The study is based on the analyses of faunal materials from 10 archaeological sites from Eastern Middle Sweden dating to approximately 3800 – 1850 B.C. The mainland faunal assemblages studied are mainly burnt and highly fragmented. The soil conditions have not enabled preservation of unburnt bones. Fragile fish bones are highly affected by burning and taphonomic processes which have a strong impact on their representativeness. This is exemplified by comparing the burnt bone materials with previously analyzed unburnt faunal assemblages from the mainland. The results showed a marked predominance of fish specimens in comparison to mammals and birds within the unburnt assemblages. The burnt bone materials showed a striking preponderance of marine mammals. The burning process causes high fragmentation and brittleness which impairs identification and quantification of the bones. Quantifying different species by their presence per excavation unit or context as a complement to summary data, showed that in particular the low and medium frequency species were handled more often than summary data indicate. Intra-site studies of burnt bones at the mainland site Fräkenrönningen showed that fish and mammals were mostly deposited in certain areas of the site. These results demonstrate the importance of performing detailed studies of the taphonomic history of the faunal assemblages.

At the Ajvide site on the island of Gotland, centrally located in the Baltic Sea, the archaeological material is unburnt and well preserved. Large amounts of faunal remains, and more than 600 fishhooks have been unearthed. Replicas of fishhooks from this homogeneous assemblage were subjected to strength test, osteometric, morphological, and breakage studies. Results point to an elaborated fishing technology for capturing medium sized cod in the waters some distance from the coast. Incremental studies of the cod otoliths (ear stones) from Ajvide show that most of the cod were captured in fall and winter, and not only during the spawning season in spring and summer. A comparison with the contemporaneous Jettböle site on the Åland islands further north in the Baltic Sea, involved fine mesh sieving and resulted in the recovery of very small herring bones. It also showed that in general smaller cod and herring were captured at Jettböle, which can be related to the shallower waters of the archipelago surroundings close to that site. The ecological conditions for marine species such as cod and herring were somewhat different during the Neolithic compared to the modern Baltic Sea. The growth pattern for cod indicate a more rapid growth for young cod but with a lower asymptotic length compared to modern cod. Although selectivity is demonstrated, Neolithic exploitation of medium sized cod had far lower impacts on the stocks than the modern fishery.

Burnt bone assemblages are valuable although the taphonomic histories are complicated. However, evaluating problems and possibilities with burnt fish remains, considering the impact of local and regional environments in relation to the captures at the sites, and studying spatial patterns provided an approach to a better understanding of the Neolithic fisheries at the mainland sites.

Keywords: fisheries, local and regional ecosystems, species variation, burnt and unburnt bones, representativeness, contextual quantification, fishing technology, spatial patterns

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In memory of

Inga and Arne Björkegren

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LIST OF PAPERS

This thesis is based on the following papers, which will be referred to by their roman numerals

Paper I

Carina Olson and Yvonne Walther. 2007. Neolithic cod (*Gadus morhua*) and herring (*Clupea harengus*) fisheries in the Baltic Sea – in the light of fine-mesh sieving. A comparative study of subfossil fishbone from the late Stone Age sites at Ajvide, Gotland, Sweden and Jettböle, Åland, Finland. *Environmental Archaeology*, Vol. 12(2): 175-185.
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Paper II

Carina Olson, Karin Limburg, and Mikael Söderström. 2008. Stone Age Fishhooks – how were they dimensioned? Morphology, strength test, and breakage pattern of Neolithic fishhooks from Ajvide, Gotland, Sweden. *Journal of Archaeological Science* 35: 2813-2823.
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Paper III

Karin Limburg, Yvonne Walther, Bongghi Hong, Carina Olson, and Jan Storå. 2008. Selectivity across the millennia. Prehistoric vs. modern Baltic Cod fisheries. *Proceedings of the Royal Society B*, doi:10.1098/rspb.2008.0711,(2008) pp. 1-7.
(Reproduced with permission from PRSB Publishing.)

Paper IV

Carina Olson, submitted
Middle Neolithic Fisheries Along the East Coast of Middle Sweden. On the Taphonomy of Burnt Fish Remains. In: Larsson, Å. M. & L. Papmehl-Dufay (Eds). *Uniting Sea II. Stone Age Societies in the Baltic Sea Region*. OPIA. Department of Archaeology and Ancient History, Uppsala University.

Paper V

Carina Olson, Niclas Björck, and Jan Storå, manuscript.
Huts and Deposition of Refuse at Fräkenrönningen, a Neolithic Coastal Dwelling Site in Eastern Middle Sweden.

PREFACE

It started with the Neolithic coastal site Fräkenrönningen in 1994, with a challenge to try to identify the strongly fragmented burnt bones from that site. The seal remains were numerous, land mammals and birds mostly few, and fish, despite being the second largest animal class, still much fewer than the seals. This pattern of the faunal composition was repeated at the osteological analyses of the burnt faunal remains from Södra Mårtsbo, Vedmora, Hedningahällan, and Högmossen. Sittesta, where both unburnt and burnt bones were unearthed, was a little different but still in a rather poor state of preservation. The unburnt and enormous amounts of well preserved fish bones from Ajvide and Jettböle were quite a contrast, and fantastic to work with. During my time as a PhD student I have had the opportunity to partly finance my studies by analyzing the faunal remains of all recent large-scale excavations of Neolithic sites from Eastern Middle Sweden. I could later incorporate these faunal assemblages within my own research.

The character and morphology of the burnt bones are, except for being altered by the burning process, also, of course affected by the general taphonomical processes, which sometimes makes, in particular, the small fish bones difficult to identify. To improve my identification skills in fish osteology, I spent much time studying the comparative fish collection at the laboratory. Since this collection was not complete, I bought different species of fresh fish and defleshed them, an excellent way to get familiar with fish anatomy, and the skeletal variety or similarity between different fish species.

Despite the difficulties and problems involved with analyzing burnt bones, I decided to further investigate the burnt materials to see how much basic data these could possibly provide for the interpretations of prehistoric handling of animals. Although the amount of fish bones was much lower than those of marine mammals at all the sites with burnt faunal remains, I was rather convinced that if people had chosen to live by the sea, fishing must have been an important source of subsistence to them. So, even though I was aware of the problems of fishbone representativeness at archaeological sites, this challenged and inspired me to further study, and to look deeper into the Neolithic fisheries.

1. INTRODUCTION

Fish must be one of the most reliable sources of subsistence. There are more species of fish than mammals and birds. Fishes live in lakes, rivers, streams, estuaries, and seas. They often occur in numerous amounts or shoals, and are predictable in behaviour and amazingly productive. During spawning periods, many fishes are easily reached, and can be captured in large numbers. There is little doubt that the lives of most prehistoric peoples included fishing in one way or another. This is indicated by the wealth of fish remains and preserved fishing implements from archaeological sites.

When the Ancylus Lake transformed into the Litorina Sea, at the onset of the Mesolithic, fresh water was continuously replaced by inflowing saline water (e.g., Voipio 1981). Favourable conditions for the production of plankton were created, and the biomass of herring strongly increased, which attracted predatory species such as cod into the waters of the Litorina Sea (Lepiksaar 1986). People started to occupy the coastal areas to exploit the rich marine resources prevailing at the time. The coastal settlements continued to increase during the Neolithic, in spite of the fact that a completely new lifestyle based on farming and animal husbandry was introduced in Scandinavia at that time. That was the start of what, over the long term, would more or less replace a subsistence based on wild resources. Nevertheless, during the Neolithic, many people lived as fishers, hunters and gatherers along our coasts, rather than relying on the production of grain and domestic meat. It is on these coastal people and their foraging lifestyle that I have focused, with an emphasis on their fisheries.

To study fish remains from archaeological sites involves, except for the osteological analysis, the study of the prehistoric local biotopes, marine environments, habitats of the fishes, and fish species behaviour, which in turn leads to the study of capture methods, and the technology required to maintain these methods. Due to the fragility of the fish skeletons, sampling, identification, quantification, and taphonomic impact are also issues that need special consideration when working with archaeological fish remains. These issues, together with the variability in size, shape, and physical character of fish compared to other single vertebrate groups, constitute a further challenge to the osteological analysis.

Background

There are a number of key studies and publications in fish osteology that form a solid basis for the research in archaeological fish remains. Richard W. Casteel published “Fish Remains in Archaeology” in 1976, an indispensable work for zooarchaeologists dealing with fish. It covers essential methods needed for fishbone analysis, described in detail. Alwyne Wheeler and Andrew K.J. Jones published “Fishes” in 1989, which, along with methods for fish analysis, discusses fish ecology, recovery methods, sampling strategies, sieving, and taphonomy.

The fish fauna history of the Scandinavian Peninsula has been described in detail by Sven Ekman, in his important work from 1922. A zoologist involved in all issues related to subfossil faunal remains was Johannes Lepiksaar. With his broad knowledge of fish anatomy, Lepiksaar carried out many analyses of prehistoric fish remains important to archaeology. He was also proficient in the Holocene history of the vertebrate fauna in Northern Europe, and the taphonomical processes that affected bones (eg. Lepiksaar 1967, 1974, 1977, 1986, 1989). Dirk Heinrich worked together with Lepiksaar on the analysis of the fishbone material from the well known German site Haithabu, located in Schleswig-Holstein, from which they published their observations and results (1977). This publication, which also contains photographed skeletal elements of different fish species, is an important document of fish osteology. Heinrich is also active within the ICAZ (International Council for ArchaeoZoology) Fish Remains Group, founded in 1981, dealing with fish remains from archaeological sites, fish trade, and fish consumption in prehistoric, and historic times.

Among the first Swedes to work with fish osteology was Ludvig Hedell who analyzed the numerous animal remains from the Neolithic site Åloppe in the province of Uppland, at the beginning of the last century (Hedell 1902 unpubl. Antiquarian-Topographical Archives, in Olson 1994, and Sönnergren 2008). Among the present workers is Leif Jonsson (1988, 1995, 1996), who has analyzed many Swedish archaeological fishbone materials, with a focus on those from western and southern Sweden. He possesses a genuine knowledge of the osteology of both fresh water and marine fish species.

Going further south in Scandinavia, investigations in Denmark have contributed a great deal to the knowledge of prehistoric fisheries. Nanna Noe-Nygaard dealt with the aquatic resources from the Danish Mesolithic inland sites (1983). Inge B. Enghoff has investigated the fisheries from numerous archaeological sites in Denmark, covering the Mesolithic, Neolithic, Bronze Age, Iron Age, and medieval times (1983, 1986, 1989, 1991, 1994, 1995, 1996, 1999, 2003, 2006; Enghoff *et al.* 2007). She has analyzed fish remains, and highlighted the importance of the retrieval of fish remains, and the use of fine-mesh sieving for an optimal recovery of fishbone. Her results and discussions around prehistoric fishing have been of great value, not only in my studies comparing Neolithic and Mesolithic fisheries, but also as a source of inspiration for the understanding of Stone Age fisheries in general. Lembi Lõugas has dealt with the post-glacial development of the vertebrate fauna in Estonian water bodies (1997). Her study was based to a great deal on bone finds from archaeological sites in Estonia. Many of these finds were fish remains from the coasts of the Estonian islands and mainland. She described the history of the fish species present in the Baltic Sea, where some were relicts from the glacial period, while others appeared during the course of the Holocene. She has also discussed Stone Age fishing strategies in Estonia (1996), and concludes that the greatest change in fish exploitation, which occurred during the Neolithic, was caused by the large quantities of marine species available in the Baltic Sea in this period. The rich marine resources drew people to the mainland coasts and the islands, as occurred throughout the entire Baltic region at the time. Lõugas also investigated the Iron Age fisheries at Birka, Sweden in comparison with Estonian sites from the Iron Age and medieval period (2001).

A few Swedish studies of Neolithic bone materials have paid special attention to fish remains. Both Lepiksaar (1974) and Aaris-Sørensen (1978) emphasized the importance of the fisheries at the Neolithic sites Äs and Korsnäs on the East coast of Sweden. According to them, the various fish species' remains from these sites, some of which were found in large quantities, indicated the proximity to and utilization of rich aquatic environments. Lindqvist (1997) underscored the importance of fine-mesh sieving when investigating parts of the bone material from the Ajvide D-upper area. He noted that the mean weight per specimen of the fish remains decreased considerably, when using a fine-mesh sieve of one millimeter instead of a standard 4-5 mm mesh. Segerberg (1999) highlighted the fisheries at the early Neolithic site Anneberg in Eastern Middle Sweden, where her aims to find small fish species like herring by fine-mesh sieving and flotation, resulted in the largest recovered fish assemblage so far from the Swedish mainland. P.G.P. Ericson performed the osteological analysis of the faunal assemblage from Anneberg.

The Litorina Sea stage, subboreal climate, and marine environment

During the Holocene, several changes in the aquatic environment of the Baltic Sea basin occurred (eg. Björck, 1995a). Periods of freshwater were replaced by those of inflowing saline seawater. The changes affected the mammal, bird and fish faunas, which had to adapt to new ecological conditions (habitats and trophic relationships) as the changes arose (e.g. Lepiksaar 1986; Liljegren & Lagerås 1993; Lõugas 1997). During the Litorina Sea stage, ca 8000-3000 B.P. (e.g. Sohlenius & Westman 1996; Sohlenius *et al.* 1996; Andrén *et al.* 2000) a period covering the Mesolithic and nearly the whole Neolithic period, saline water began to enter the Baltic basin. After the Mastogloia stage at around 7500 B.P. the brackish condition of the Baltic was established, and salinity reached its first maximum between 6700-6400 B.P., followed by two smaller maxima at 4600 and 3200 B.P. in the Gotland Basin (Brenner 2005). The saline Litorina Sea offered possibilities for a subsistence based on sea mammals and marine fish, which is indicated by the increasing number of coastal settlements and osteological remains from this period (e.g. Björck 1995; Andersen 1995; Christensen 1995; Nunez 1996; Lõugas 1997). After that, salinity slowly decreased owing to isostatic land uplift, which reduced the inflow of Atlantic seawater through the Dana river system, the Great Belt, and Öresund into the Baltic Sea (e.g. Björck 1995b; Brenner 2005). After the warm and humid Atlantic chronozone (8000-5000 B.P.), the sub-boreal period followed with hot, dry summers created by intensified high pressure zones. Deciduous forests reached 60ºN at the time, and the estimated sea surface temperatures (SST) in the Baltic were up to 4ºC higher than today (Davis *et al.* 2003; Emeis *et al.* 2003).

The changing marine environment during the Holocene may be understood through studies of shore displacement. A complicated pattern of isostatic uplift in Eastern Middle Sweden during the late Holocene was verified when shoreline configuration over time, and the isolation of lake basins through diatom analysis were studied (Risberg *et al.* 2005; Risberg 2008). The changing topography in Eastern Sweden has been so obvious that the dynamics of the landscape must be considered, in order to understand the cultural development over time in this area. The results from the investigations enabled a construction of palaeogeographical maps following the ancient shore-lines, e.g., contour lines of 50, 45, 40, and 35 meters above sea level, which correspond to 5800, 5300, 4600, and 4000 cal. yr B.P. respectively (Risberg 2008), whereof the latter three fall within the Neolithic period. Åkerlund (1996) studied human responses to shore displacement in Eastern Middle Sweden during the Stone Age, where archaeological evidence was evaluated against geological evidence at regional, subregional, and site levels. She observed that the location of sites close to the shores occurred in all periods, but that it was particularly evident for the Pitted Ware Culture sites during the Middle Neolithic period (Åkerlund 1996:139). Ericson (1989) has suggested that the possibilities for fishing was the main reason for the location of these settlements. Other than subsistence related criteria for the settlement patterns have also been considered, emphasizing a more ritual character of these shore-bound places (Carlsson 1998; Gill 2003)

The Neolithic coastal settlements

The Neolithic coastal complex inhabiting the coastal areas along the eastern coast of the Swedish mainland, and the large islands of the Baltic Sea, has in Sweden been defined as the Pitted Ware Culture, named after the pottery, often ornamented with round, depressed pits. The large amounts of bone remains unearthed at the Pitted Ware Culture sites have been the subject of discussions and numerous publications during the past 30 years or more. However, only a few of these discuss fish remains to any greater extent (e.g. Ekman 1974; Löfstrand 1974; Lepiksaar 1974, 1986; Aaris-Sørensen 1978; Gräslund 1978; Welinder 1976, 1978, 1997; During 1986; Browall 1986; Wyszomirska 1986, 1988; Ericson 1989; Österholm 1989; Lidén 1995; Lõugas

1996a, 1996b, 1997; Björck 1997, 1998; Edenmo *et al.* 1997; Lindqvist 1997; Lindqvist & Possnert 1997; Rowley-Conwy & Storå 1997; Segerberg 1999; Götherström *et al.* 2001; Storå 2001, 2002; Malmer 2002; Mannermaa 2002; Olson *et al.* 2002; Eriksson 2003; Stenbäck 2003; Storå & Ericson 2004; Fornander 2006; Mannermaa & Storå 2006; Olson & Walther 2007; Bäckström 2008; Mannermaa 2008; Olson *et al.* 2008, Storå *et al.* 2008).

Although fish and seal bones are most common, terrestrial mammals such as pigs occur in rather large quantities in some of the unburnt faunal remains (e.g. Hedell 1902 unpubl.; Ekman 1974; Lepiksaar 1974; Aaris-Sørensen 1978; Burenhult 1997; Rowley-Conwy & Storå 1997; Eriksson 2003; Fornander 2006). Bird remains are often present in the bone materials, generally uncommon at the mainland sites, but more abundant on the large islands (Ericson & Hernández Carrasquilla 1997; Mannermaa 2002; Mannermaa & Storå 2006; Mannermaa 2008). Despite the fairly large amounts of wild boar bones, a marine focused diet has been confirmed by stable isotope studies of human remains from Ajvide and Västerbjers on Gotland, Jettböle on Åland, Korsnäs on the Swedish mainland, Köpingsvik on Öland, and Naakamäe in Estonia, which all indicate a heavy dependence on marine proteins (Lidén 1995; Lougas *et al.* 1996a; Lindqvist & Possnert 1997; Eriksson 2003; Fornander 2006; Eriksson *et al.* 2008). Paradoxically, the consumption of fish proteins is hardly confirmed by the stable isotope analyses, despite the large amounts of fish remains found at most of these sites.

The importance of fishing within the subsistence economy of the Neolithic coastal sites is generally speaking poorly understood. This may be due to an underestimation of the magnitude of fishing because of a preservational bias in favour of mammal bones, especially those of seals (Ericson 1989). This is particularly evident within the burnt materials. In the acidic soils, which are most common at the archaeological sites of mainland Eastern Middle Sweden, mainly burnt bones are found. Burnt bones preserve better under these conditions since they are more resistant to decay due to the loss of organic components after burning (e.g. Gejvall 1969; Holck 1987; During 1992:24; Lyman 1994a:389). The burning of the bones causes shrinkage, deformation, and also makes them more brittle. The brittleness is the main reason for the high fragmentation rate of burnt bones, which seldom exceed 1 x 1 cm (e.g. Ukkonen 2001). Fish bones are often much more fragmented. Burnt faunal remains of fish have previously not been analyzed extensively. We lack information beyond summary data of identified species, and previous interpretations of prehistoric fishing have relied heavily on summary data of complete sites. To some extent this is true also for unburnt assemblages. In general the find circumstances or depositional patterns of fish remains have received little attention (but see Segerberg 1999). Summary data are necessary and should always be included in the analysis of skeletal materials, but they should be complemented with information on find circumstances, anatomical and chronological distribution.

This thesis will present analyses of several large assemblages of fish bones. The main objective is to investigate fishing during the Neolithic Stone Age in Eastern Middle Sweden, including the Island of Gotland and the Åland Islands. The impacts of recovery techniques and preservation as well as identification, quantification and the representativeness of archaeological assemblages of fish bones are examined and evaluated. The character of the fisheries is evaluated in relation to the local aquatic environment and accessibility. The goal is also to gain a better understanding of the coastal settlement on the basis of fishing patterns and fishing technology such as the production of fishhooks.

Paper I addresses topics which are related to the recovery of fish-remains and especially how sieving strategies affect the quantitative patterns. Paper II presents an analysis of fishhooks from the Neolithic site of Ajvide on Gotland and the manufacture and design of fishing gear. Paper III presents an analysis of size distribution, growth and seasonal capture patterns on the basis of otolith studies of caught cod (*Gadus morhua*) at Ajvide. Paper IV presents an analysis of burnt fish remains from Neolithic coastal sites in Eastern Middle Sweden. Fishing patterns on four sites are analysed the quantitative patterns evaluated. Paper V presents an analysis of burnt faunal remains from the Neolithic site Fräkenrönningen in Gästrikland. Intra-site patterns in deposition of burnt bones are investigated in order to evaluate the taphonomic history of the faunal assemblage. The study has the character of a "re-visit".

2. MATERIAL

Approximately 300.000 bone fragments deriving from sites on the mainland of Eastern Middle Sweden, the island of Gotland, and the Åland islands form the basis for this thesis. The bone materials were analyzed between 1994 – 2006 (Olson 1995, 1996, 1999a, 1999b, 2003, 2004, 2006a, 2006b; Olson & Walther 2007; Olson *et al.* 2008) (Table 1).

Sites of the study

The analyzed faunal materials derive from sites along 600 kilometers of the mainland and archipelago coastlines of Eastern Middle Sweden, Ajvide on Gotland, and Jettböle on Åland, (Figure 1). All sites are classified as belonging to the Pitted Ware Culture, although Hedningahällan and Bjästamon also show influences of other Neolithic

Table 1. Number of Identfied Specimens (NISP), weight, and condition of the analyzed bone materials.

Sites	Identified fishes	Unidentified fishes	Identified birds	Unidentified birds	Identified mammals	Unidentified mammals	Unidentified fish/ birds/mammals	NISP	Total weight g	Burnt/unburnt	Mean weight g
Sittesta	32	19	10	18	1017	5953	709	7758	2214	UB/BB	0.29
Högmossen	507	859	1	5	6439	24657		32468	6273	BB	0.19
Fräkenrönningen	1256	1350	7	7	5624	46744		54988	14738	BB	0.26
Södra Mårtsbo	1201	1545	20	5	2947	33562		39280	7345	BB	0.19
Hedningahällan	113	50	3	4	3316	18493		21979	5410	BB	0.25
Vedmora	77	66	0	1	1704	9228		11076	2384	BB	0.22
Kornsjövägen[1]	6	3	1	0	1214	5423		6647	1240	BB	0.19
Bjästamon[2]	1092	7375	33	179	11613	62165	24870	107327	10544	BB	0.10
Ajvide[3]	3649	3095	table 3	table 3	table 2	table 2		6744	328	UB	
Jettböle[4]	3319	9774	table 3	table 3	table 2	table 2		13093	332	UB/BB	
Total	11252	24136	75	219	33874	206225	25579	301360	50808		0.17

[1] skeletal elements from area B and C. [2] skeletal elements from wall structures analyzed by Sigvallius & Storå, and features by Olson (Olson et al. 2008). [3] only fish remains analyzed by Olson, mammals by Lindqvist (1997), Rowley-Conwy & Storå (1997), Storå (2001), and birds by Mannerma (2008). [4] only fish remains analyzed by Olson, mammals by Storå (2001), and birds by Mannermaa (2008) Mammals and birds are documented in tables 2 and 3.

ceramic styles. The radiocarbon datings (calibrated) span from the early to the late Neolithic. The majority of dates belong to the middle Neolithic. Among other sites in the Baltic region, not analyzed by the author, that will be particularly referred to for comparisons of fish remains are Korsnäs in the province of Södermanland (Aaris-Sørensen 1978), Äs in Västmanland (Lepiksaar 1974), Åloppe and Anneberg in Uppland (Hedell 1902 unpubl., Segerberg 1999), Dalkvarn 1 and Jättendal in Hälsingland (Jonsson & Wallander 1993/94; Holm 2006).

Sittesta in Ösmo parish in the province of Södermanland, the southernmost of the sites, was archaeologically excavated in 2005 by UV-Mitt, Stockholm. The excavated area is 6500 m^2. The total weight of the bone material is 4.3 kg, whereof 2.2 kg were selected for osteological analysis, unburnt (1.6 kg) and burnt (0.6 kg) bones (Olson 2006). The site has radiocarbon datings within the interval of 3300 – 2500 B.C. It was located on a southern shore of an inlet on the eastern side of an island, today known as Södertörn, not far from the numerous islands and skerries of the outer archipelago (Kihlstedt *et al.* 2007).

Högmossen in Tierp parish in the province of Uppland, was excavated in 2004 by UV-GAL, Uppsala. The total excavated area covers 4000 m^2. Approximately 14 kg of burnt bones were retrieved, and a number of unburnt enamel fragments of human teeth were recovered from a burial centrally located within the site area. A selection of 6.3 kg from different areas covering 120 m^2 was subjected to osteological analysis. The site was inhabited around 3500 – 3200 B.C.

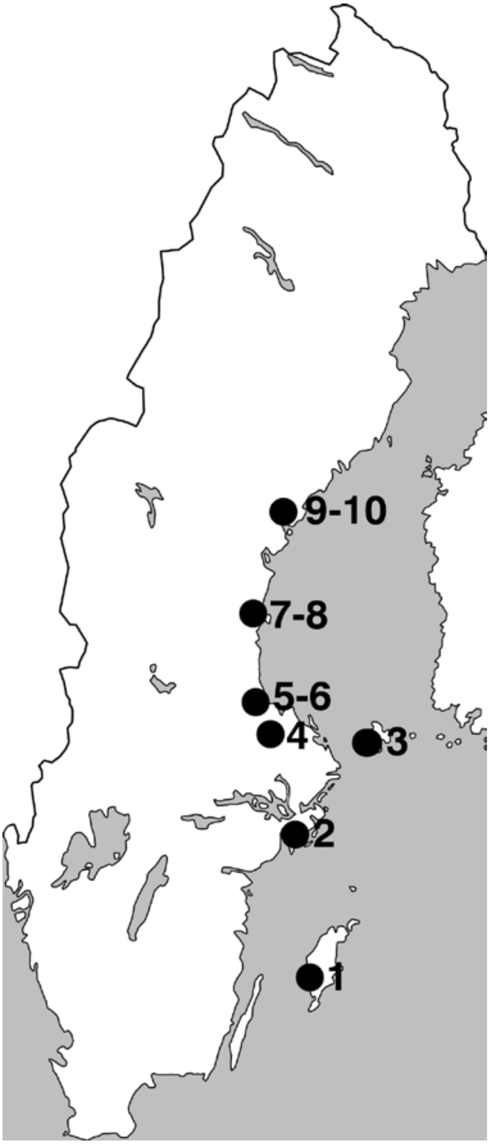

Figure 1. Map of the Baltic Sea Region with the location of the studied sites.

1	*Ajvide*
2	*Sittesta*
3	*Jettböle*
4	*Högmossen*
5-6	*Fräkenrönningen and Södra Mårtsbo*
7-8	*Hedningahällan and Vedmora*
9-10	*Kornsjövägen and Bjästamon*

It was located on an eastern slope of a north-heading peninsula of the mainland, overlooking a bay and numerous islands of the outer archipelago. The estuary of the river Dalälven was also located in this area, some distance north of Högmossen (Björck *et al.* 2008; Björck & Lindberg 2008).

Fräkenrönningen in Valbo parish in the province of Gästrikland was archaeologically investigated in 1993 by The County Museum of Gävleborg. The excavated area of the site is 542 m^2. The bone remains consisted of 14.7 kilos of burnt highly fragmented specimens of a few terrestrial but mostly marine mammals, fishes, and birds. One unburnt fragment consisting of a human tooth (enamel) was recovered from a burial within the site area, which most probably was occupied within the interval of 3000 – 2800 B.C. Fräkenrönningen was located on a southern slope of the mainland adjacent to a shallow inlet of the inner archipelago overlooking numerous islands and skerries extending further at sea (Olson 1996; Björck 1998).

Södra Mårtsbo in Valbo parish in the province of Gästrikland, 3 km north of Fräkenrönningen, was also excavated in 1993 by The County Museum of Gävleborg. The site area covers 2500 m^2, of which an area of 312 m^2 was completely archaeologically excavated. The recovered bone material from this area was burnt, strongly fragmented, and weighed 7.3 kg. The only preserved unburnt remains were the enamel of four human teeth belonging to a burial centrally located within the completely excavated area of the site. The site is radiocarbon dated to 3300-3000 B.C. Although somewhat sheltered by the surrounding topography, the Neolithic location was rather exposed on the southern shore of a peninsula, farther out in the archipelago and closer to the open sea than Fräkenrönningen (Olson 1995; Björck *et al.* 2004).

Hedningahällan in Enånger parish in the province Hälsingland was first investigated by Hallström in 1912 (Arbman, 1945), and latest excavated in 1984 under the guidance of H. Sundlin, UV-Mitt, in collaboration with The Museum of National Antiquities, The County Museum of Gävleborg, and the National Labour Market Board in

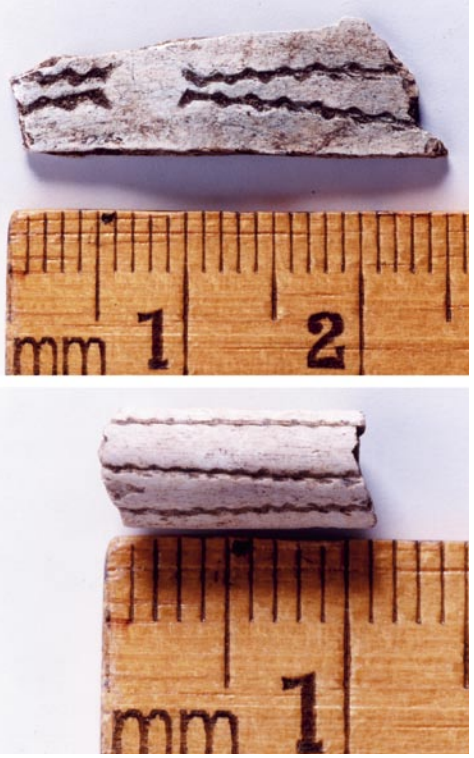

Figure 2. Ornamented burnt bone fragments from Hedningahällan, Hälsingland. Photo: Björn Dawidsson

Sundsvall). The total site area is 500 m^2. The excavated area comprises 122 m^2. The selected burnt bone material analyzed by the author weighs 5.4 kilos. The weight of the totally recovered fauna material is 17.2 kilos. Exclusively for this material, was the additional finds of ornamented bone fragments (Figure 2). The radiocarbon datings span between 2950 – 1850 B.C. Hedningahällan was located on an eight meter high rock exposed to the southeast, facing a large bay, and further out east, scattered islands and skerries of the outer archipelago. The rock at its widest is 35 meters. The settlement area slopes 5-6 meters, but contains two plane level areas of 12 x 8 and 10 x 5 meters respectively (Schierbeck 1994; Olson 1999; Holm 2006).

Vedmora, also in Enånger parish in the province of Hälsingland, was excavated in 1996 by the County Museum of Gävleborg. The excavated area is 722 m^2. The bone material is burnt and weighs only 2.4 kg. According to radiocarbon datings the site was in use between 2900 – 2400 B.C. During the Neolithic, when the sea level was 45 meters higher than today, Vedmora was located on a southern slope of the western side of a large island, measuring 5 x 1.5 km, and sheltered by a wide lagoon in the south. The island was separated from the mainland in the west by a 300 meter wide strait. The outermost islands and skerries of the archipelago were ca. 8 km east of the site (Björck & Björck 1999; Olson 1999).

Kornsjövägen in Nätra parish in the province of Ångermanland, was excavated in 2002 by Angaria AB. The excavated area is 12500 m^2. The selected analyzed bone material (from area B and C) is burnt and amounts to 1.2 kg. The total amount of recovered faunal remains weighed 4.5 kg. The radiocarbon datings span between 3800 – 1950 B.C. The site, sheltered by high hills, was located only ca. 400 meters west of the partly contemporaneous Bjästamon site, on a southern slope of the mainland, on the shore of an inlet with an east-west direction. The archipelago environment had large islands close by, and islets and skerries further out at sea (Olson 2003; Lindqvist 2008).

Bjästamon, located in Nätra parish in the province of Ångermanland, is the northernmost site of this study. It was excavated in 2002 by UV-Mitt, Stockholm. The excavated site area, which consists of clearly defined features and wall structures, is totally 40200 m^2. Faunal remains comprising nearly 11 kg were selected for an osteological analysis from 17000 m^2 of the complete site area. Bjästamon yielded 68 kg of burnt bones, which is the largest burnt bone material found so far at an East coast site. The Neolithic occupation is divided into two phases according to the radiocarbon datings and artefact categories; 2800-2400 B.C. = phase 1, and 2400-2100 B.C. = phase 2. During the Neolithic the site was located on a mainland slope towards the southeast, within an environment consisting of shallow inlets, narrow straits, nearby islands, two freshwater lakes and the open sea within a reasonable distance (Holback *et al.* 2004; Olson *et al.* 2008; Runeson 2008).

Ajvide is situated in Eksta parish in the province (and island) of Gotland. The total site area is ca. 200 000 m^2. Partial areas have been continuously investigated since 1983 by leaders and students from the Archaeological Departments at Stockholm University and Gotland University during seminar excavations. Total excavated area so far is 2200 m^2. The site comprises three areas with Pitted Ware culture finds; area C, area D-upper, and area D-lower. 2900 kilos of pottery and 2200 kilos of faunal remains have hitherto been recovered. From a soil sample volume of 15 liters from the D-upper area, 328 g of fish bones were retrieved and analyzed. The radiocarbon datings show that the large burial ground is slightly younger than the cultural layers, falling between 2700-2300 B.C. The main period of use during the Neolithic was between 3100–2700 B.C. (Burenhult 1997). The analyzed fish remains were recovered from the D-upper area belonging to the period approximately 2900-2700 B.C. Ajvide was situated on the shore of the southwest coast of the island of Gotland. Adjacent to the site in the south, was a lagoon sheltered by an island. To the west Ajvide was facing the open sea and farther out, ca. 6-7 kilometers, the islands of Stora Karlsö and Lilla Karlsö (Burenhult 1997a, 1997b, Österholm 1989, 1993, 1995, 2002; Norderäng 2000-2007; Paper I).

Jettböle is located in the parish of Jomala on the Åland islands. The site is approximately 20.000 m^2. Jettböle I was excavated in 1905, 1906, 1908 and 1911 by Björn Cederhvarf. Jettböle II was excavated in 1906 and 1908 (Cederhvarf 1912), and a test excavation was also performed in 1999-2000 to more thoroughly examine the stratigraphy (Storå 2004) The total excavated site area is approximately 700 m^2. From a soil sample volume of 14 liters, 332 g of fish bones were retrieved and analyzed (Paper I). The samples derive from square 254 of trench A, Jettböle I, the older part of the site, and were collected by Björn Cederhvarf in 1911. The majority of the bones were unburnt, but a small amount of burnt bones were also recovered. The skeletal material from Jettböle I is the largest and best preserved bone sample from the Stone Age found in Finland According to the radiocarbon datings the site was occupied from c. 3300-2800 B.C. Jettböle had two settlement phases, separated by type of pottery and altitude above sea level, known as Jettböle I, and Jettböle II. Jettböle's location within the Åland archipelago offered access to fish species inhabiting straits, shallow inlets, and large bays. Farther out in the open sea, Jettböle was surrounded by large and small islands and skerries, but the mainland was far away both east and west (Cederhvarf 1912; Winge 1914; Meinander 1986; Nunez 1986; Lidén *et al.* 1995; Götherström *et al.* 2001; Storå 2001; Stenbäck 2003; Mannermaa 2008).

3. METHODS

Osteological analyses of fish remains involve identification, quantification, size and weight estimations on the basis of osteometry, and interpretation of incremental annuli of certain skeletal elements for assessment of age, growth, and season of capture (e.g. Casteel, 1972, 1976; Lepiksaar and Heinrich 1977; Morales & Rosenlund 1979; Enghoff 1983; Brinkhuizen & Clason 1986; Weatherley & Gill 1987; Wheeler & Jones 1989; Colley 1990).

When recovering fish remains at archaeological sites, fine-mesh sieving, using no coarser than 2 mm screens, is crucial for the interpretation and understanding of prehistoric fisheries (Paper I). In this study fine-mesh sieving of cultural layers and/or soil-samples was conducted at Ajvide, Jettböle, Sittesta, Högmossen, Södra Mårtsbo, Vedmora, and Bjästamon. Large amounts of fish would have been lost at most of these sites, and the herrings (*Clupea harengus*) would have been much fewer at Ajvide, and hardly present at Jettböle, if only a standard mesh-size of 4-5 mm had been used (Paper I).

The condition of the burnt bones made investigations other than identification and quantification difficult. The state of the majority of the unburnt fish remains from Ajvide and Jettböle were, however, mainly excellent, and appropriate for osteometric methods, and to some extent, age and seasonal studies. Ajvide was the only site where otoliths (from cod only) were preserved, which could be used for length, weight, growth, and season of capture estimations.

The morphology, strength, and fracture patterns of bone fishhooks from Ajvide were studied in Paper II. The specific methodology adopted is described therein.

Identification

The identification of all fish bones in the present study has been carried out at the Osteoarchaeological Research Laboratory at the Department of Archaeology and Classical Studies, Stockholm University, using the comparative collection at the laboratory, and the author's own collection. The fish skeleton collections at the Swedish Museum of Natural History in Stockholm, the Museum of Natural History in Gothenburg, and the former Department of Osteology at the Museum of National Antiquities, have been used in certain cases. As far as possible, the fish remains were identified to specific skeletal element, and side, if paired. Fish vertebrae were identified to vertebral position 1 and 2, when possible, otherwise vertebrae were identified as precaudal or caudal.

Quantification

The goal was to count all recovered skeletal elements of mammals, birds and fishes from each site. This was possible for most of the specimens in all cases. However, the very small fragments of fin-rays and ribs of fish, impossible to identify to species, were not counted individually. The information lost was considered negligible. Number of identified specimens (NISP) was consequently used on all faunal materials (Lyman 1994b; Grayson 1984). For some of the burnt materials, a quantification method considering the occurrence of seals and fishes in number of excavation units and/or contexts was applied and contrasted to NISP summary data (Paper IV). The minimum number of individuals (MNI) was counted when there was more than one of a specific skeletal element from the same side of the body of a species. Vertebra position 1 or 2, and the left or right otolith, depending of which showed the largest quantity, was used to estimate the MNI of cod at Ajvide to secure a correct number of individuals when calculating cod body lenghts and weights for Paper I, II and III. Also, for all other fish species, skeletal elements have been assessed to side whenever possible, and the number of vertebra position 1 has been counted, in order to secure a basis for MNI estimations.

Size and weight estimation

From Ajvide and Jettböle (Paper I) vertebra position 1 and 2, and otoliths of cod (Gadus morhua) were used for the estimation of the total length (TL) of the fishes, due to the numerous amounts and relatively intact condition of these skeletal elements. TL is the maximum length of the fish with mouth closed and tail fins squeezed together (Casteel 1976). No other fish species but cod could provide sufficient quantities of an intact specific skeletal element appropriate for measuring. The maximum width (w) of the posterior articular face of vertebra position 1 and 2 was measured by a digital slide caliper. The total length (TL) was calculated by using regression formulas developed by Enghoff (1983, 1994):

$TL = 87.3172 * w^{0.8260}$ $r = 0.9970$
(vce pos 1)

$TL = 86.1390 * w^{0.8162}$ $r = 0.9972$
(vce pos 2)

From Ajvide, otoliths (ear stones) were also used for body length estimations of cod (Papers II and III). Since the otoliths were mostly more intact on their widest axis than at the rostral and posterior tips, the otolith maximum width (OMW) was measured. A regression formula developed using modern Baltic cod otoliths and TL data, was used to calculate the total fish length (Olson et al. 2002):

$TL = -13.34 + 9.73 * OMW$ $r^2 = 0.92$

The weight estimations used in this study (Paper II) are based on a formula for length – weight relationships of the same modern-day Baltic cod, using unpublished data from the Marine Research Laboratory in Lysekil, Sweden:

$Weight=0.0039621 (TL)^{3.2375}$ $r^2=0.99$

The size estimations of herring from Ajvide and Jettböle do not rely on regression formulas for specific skeletal elements, as for cod. Insufficient quantities of appropriate skeletal elements rendered size estimations of herring infeasible. Therefore, total body lengths have not been estimated, and only a comparison of the sizes of the herring vertebrae from both sites was carried out. The length and width of the vertebral body of precaudal and caudal vertebrae from the central part of the vertebral column were measured. In this way the upper, flatter cervical vertebrae and the rearmost smaller vertebrae were avoided, when the length and width of each vertebra were measured (Paper I). Similar methods have proved to be sufficient for the estimation of average lengths of herring (Ekman 1974; Lepiksaar & Heinrich 1977)

Estimation of age and season of capture

Annual increments of cod otoliths have been used to estimate age, size at age, and size at capture (Paper III). The low quantities of other measurable bones, like the dentary bone, which can be used for age assessing (e.g. Ekman 1973:57), excluded them from the study. To read the life history of fishes accumulated in the otolith, the core of the otolith must be exposed. This was done by sectioning the otolith through the core, whereafter the surfaces of the sectioned core were ground and polished. The incremental lines show summer and winter growth zones that can be counted and measured. The last and outermost line reveals the season of capture of each fish individual (e.g., Mellars & Wilkinson 1980; Van Neer et al. 1999; Higham & Horn 2000; Van Neer *et al*. 2004) (Figure 3).

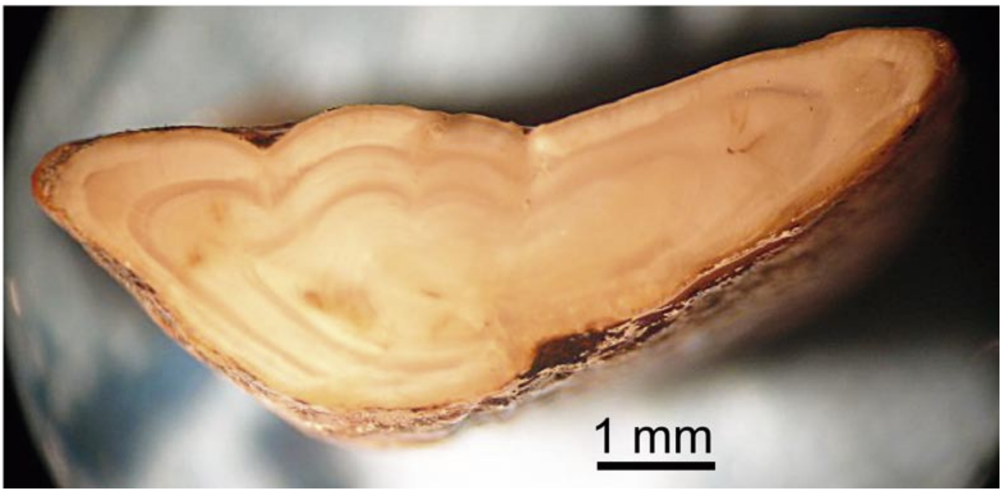

Figure 3. Sectioned Neolithic otolith from Ajvide displaying annuli. Photo: Karin Limburg

4. MAMMALS AND BIRDS

An overview of the faunal remains

The faunal remains from the coastal sites in Eastern Middle Sweden are similar in the way that bones from seal and fish are the most common. In other respects, like the species frequency rates for land mammals, birds and fishes, there are many differences between the sites, as will be seen from the NISP comparisons.

Mammals

A total of 22 mammal species were identified from all sites (Table 2). The sites with the highest number of identified species are Jettböle (n = 11), Sittesta (n = 10), and Fräkenrönningen (n = 10). The site with the lowest number of species is Vedmora with only four identified species. The largest number of identified mammal remains, 11613 specimens, was recovered from Bjästamon, followed by Ajvide (7363) and Högmossen (6365). Harp seals (*Phoca groenlandica*) and ringed seals (*Phoca hispida*) are the predominant mammals at all sites. Together with two specimens of grey seal (*Halichoerus grypus*), and unidentified seal, there is a total of 41868 specimens, compared to the second most common mammal, wild boar (*Sus scrofa*), represented by 2060 fragments. Brown bear (*Ursus arctos*) was only found at Fräkenrönningen and Bjästamon, and wildcat and/or lynx (*Felis silvestris/Lynx lynx*) at Sittesta and Södra Mårtsbo. Other less frequent mammals are porpoise (*Phocaena phocaena*), only present at Sittesta, Ajvide and Jettböle, and fox (*Vulpes vulpes*) which occurs at Högmossen, Södra Mårtsbo and Ajvide. Mountain hare (*Lepus timidus*), also uncommon, only occured at Södra Mårtsbo, Hedningahällan, Bjästamon, and Jettböle. Mustelids including badger (*Meles meles*), otter (*Lutra lutra*), pine marten (*Martes martes*) , and polecat (*Mustela putorius*) are more common at the northern sites than in the southern part of the eastern coastal area, and not present on Gotland and Åland. The only sites with remains of cattle (*Bos taurus*) are Sittesta, Ajvide and Jettböle, and the only sites with sheep or goat (*Ovis aries/Capra hircus*) are Sittesta and Ajvide. However, the chronology for the domestic animals is problematic, and often of a younger date than Stone Age (e.g. Segerberg 1999:111; Storå 2000; Eriksson 2003:21; Eriksson *et al.* 2008:14). Nevertheless, there are a few radiocarbon datings of cattle from Eastern Middle Sweden belonging to the Neolithic period at Skumparberget, Glanshammar parish, in the province of Närke, and the coastal site Trössla, Vagnhärad parish in the province of Södermanland (Hallgren 2008:127).

Table 2. Identified mammal species at the studies sites (human specimens excluded).

Mammal species	Sittesta	Högmossen	Fräkenrönningen	S. Mårtsbo	Hedningahällan	Vedmora	Kornsjövägen	Bjästamon	Ajvide	Jettböle	Sum
Cattle (*Bos taurus*)	14								2	20	36
Wild boar (*Sus scrofa*)	69	9	15	1	2				1958	6	2060
Sheep/goat (*Ovies aries*/*Capra hircus*)	1								24		25
Moose (*Alces alces*)	1		3					2		15	21
Elk (*Cervus elaphus*)										9	9
Roedeer (*Capreolus capreolus*)		2	1								3
Cervids (Cervidae)	12						2				14
Herbivore	91	40	1					2		28	162
Beaver (*Castor fiber*)		2	66		26		17	57			168
Mountain hare (*Lepus timidus*)				8	1			2		+	11
Squirrel (*Sciurus vulgaris*)									1		1
Dog (*Canis familiaris*)	2		1						63	4	70
Brown bear (*Ursus arctos*)			2					+			2
Fox (*Vulpes vulpes*)		1		1					15		17
Fox/dog (*Vulpes vulpes*/*Canis fam.*)	2							4			6
Wildcat (*Felis silvestris*)	1										1
Lynx/wild cat (*Lynx lynx*/*Felis silv.*)				1							1
Badger (*Meles meles*)		2	2								4
Otter (*Lutra lutra*)		2	3		1	1	7	2			16
Marten (*Martes martes*)	1					4		1			6
Polecat (*Mustela putorius*)				2							2
Mustelids (Mustelidae)		3	1		7	13	4	184			212
Carnivore (Carnivorae)	1										1
Harp seal (*Phoca groenlandica*)	33	75	72	51	57	23	9	50	1617	1603	3590
Ringed seal (*Phoca hispida*)	15	75	137	51	100	67	27	122	762	540	1896
Grey seal (*Halichoerus grypus*)										2	2
Seal (Phocidae)	771	6154	5318	2830	3121	1596	1148	11187	2921	1334	36380
Porpoise (*Phocoena phocoena*)	1								+	37	38
Unidentified mammals	5953	24657	46744	33562	18493	9228	5423	62165	na	na	206225
Total	6968	31022	52366	36507	21808	10932	6637	73778	7363	3598	250979

na = not available + present but not quantified (Winge 1914; Olson 1995, 1996, 1999a, 1999b 2003, 2004, 2006a, 2006b; Lindqvist 1997; Storå 2001)

Table 3. Identified bird species at the studied sites.

Bird species	Sittesta	Högmossen	Fräkenrönningen	S. Mårtsbo	Hedningahällan	Vedmora	Kornsjövägen	Bjästamon	Ajvide	Jettböle	Sum
Divers (Gavidae)									4		4
Gannets (Sulidae)									1		1
Cormorants (Phalacrocoracidae)									30	7	37
Common Eider (*Somateria mollissima*)	2								16	588	606
Mallard (*Anas platyrhynchos*)				2							2
Ducks (Anatidae)	8	+	6	10	3			5	127	321	480
Eagles,hawks,falcons (Falconiformes)		1	1	1					14	5	22
Cranes (Cruidae)									2		2
Oyster catchers (Haematopodidae)									2		2
Plovers (Charadriidae)									11		11
Waders (Charadriiformes)										4	4
Sandpipers (Scolopaciidae)									6		6
Plovers/Sandpipers (Charadriidae/Scolopaciidae)									24		24
Gulls,terns,skuas (Laridae, Stercoraciidae)		+							34	7	41
Auks (Alcidae)									192	15	207
Hooded Crow (*Corvus corone*)										1	1
Pigeons (Columbidae)									4		4
Owls (Strigidae)									1		1
Nightjars (Caprimulgidae)									1		1
Passerine (Passeriformes)									32		32
Western capercaillie (*Tetrao urugallus*)								7			7
Hazel grouse (*Tetrastes bonasia*)								3			3
Wild fowl (Galliformes)				1			1	18			20
Unidentified birds	18	5	7	5	4	1	0	179	150	292	661
Total	28	6	14	19	7	1	1	212	651	1240	2179

(Winge 1914; Olson 1995, 1996, 1999a, 1999b, 2003, 2004, 2006a, 2006b; Sigvallius & Storå 2001; Mannermaa 2008)

Harp seals tend to be more abundant in the southern part of the area, and at the sites of the large islands. The harp seals also show a higher frequency within the unburnt materials. Ringed seals are more common at the northern sites (Figure 4). This is consistent with earlier observations (Ericson 1989; Storå 2001; Ukkonen 2001).

Birds

Birds remains are few at the mainland sites, where not many species have been identified, compared to mammals and fish. This was rather expected within the strongly fragmented burnt bone remains, but also at Sittesta, where unburnt bones were more frequent than burnt, the majority (n=23) of the few bird specimens were burnt. This has affected the identification of the mainland bird bones, and very few specimens within the burnt bird remains have been possible to identify to species. The unburnt, well preserved bone remains from Gotland and the Åland islands, on the contrary, contained considerably more bird bones and a variety of identified species (Mannermaa & Storå 2006; Mannermaa 2008). The common trend at the mainland sites, and at Ajvide and Jettböle, is, that duck species (Anatidae) are most frequent. The only exception is Bjästamon where wild fowl (Galliformes) dominate, and thus this group seems to have a northerly distribution in comparison with avifauna at the other sites (Table 3).

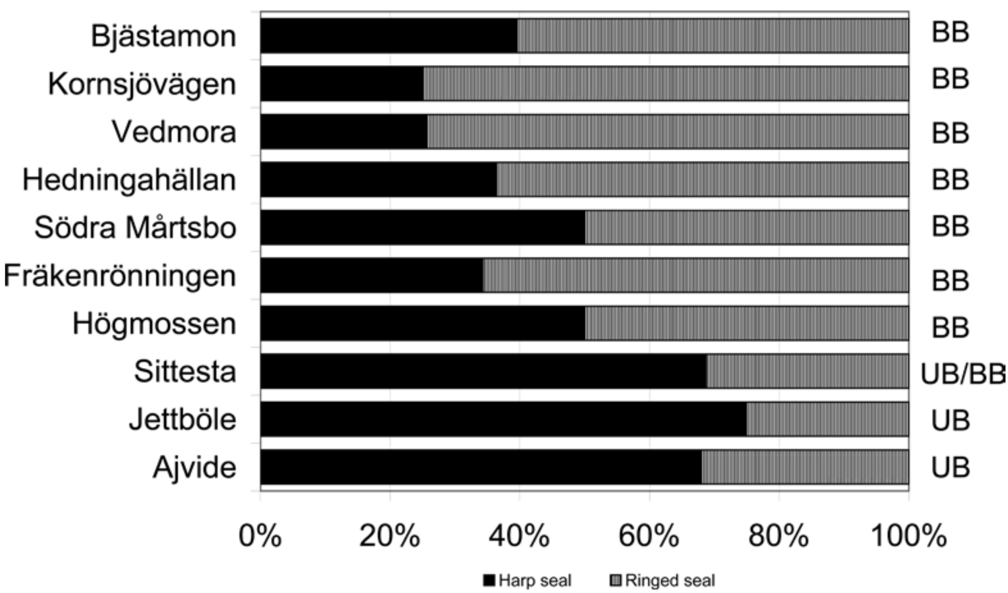

Figure 4. Seal species frequency at the sites from south (Ajvide) to north (Bjästamon)

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5. THE FISH REMAINS

Fish species distribution

The fishbone assemblages consist of skeletal elements of various species of fresh/brackish water, diadromous, and marine fish. Vertebrae are the largest skeletal find category. Cranial elements are quite numerous where preservation conditions are good. An exception was that the recovered specimens of pike were predominated by the robust dentary bone (dentale) at all sites, irrespective of preservational conditions, i.e. unburnt or burnt. Scales, mainly from perch, were rarely found, and only within the well preserved unburnt materials. The largest fishbone materials derive from Jettböle, Bjästamon and Ajvide, in sequence. Some thousand fragments fewer were recovered at Fräkenrönningen, Södra Mårtsbo, and Högmossen. The fisheries at Sittesta and Kornsjövägen are poorly represented by only a few skeletal elements. Hedningahällan

Table 4. Identified fish species at the studied sites.

Fish species	Sittesta	Högmossen	Fräkenrönningen	S Mårtsbo	Hedningahällan	Vedmora	Kornsjövägen	Bjästamon	Ajvide	Jettböle	Sum
Perch (*Perca fluviatilis*)	1	93	211	503	35	16	3	72	48	7	989
Pikeperch (*Stizostedion lucioperca*)		3	9	3		1		13			29
Percids (Percidae)		4		6							10
Pike (*Esox lucius*)	17	305	128	231	57	48		38	29	24	877
Roach (*Rutilus rutilus*)		7		8							15
Cyprinids (Cyprinadae)	1	16	64	332	2	2		4	33		454
Burbot (*Lota lota*)		3	16	10		1		4			34
Sculpin (Cottidae)				6				362			368
Whitefish (*Coregonus lavaretus*)		25		25	2			15	2		69
Whitef/Salmon (Coronidae/Salmonidae)	2	48	812	63	8	5		15			953
Salmonids (Salmonidae)	2			9	9	4	1	7	16		48
Eel (*Anguilla anguilla*)				1					2		3
Turbot (*Psetta maxima*)	1									7	8
Flounder (*Platichthys flesus*)							1	272		1	274
Flatfish (Pleuronectidae)	1	1						214	35	8	259
Cod (*Gadus morhua*)	7	1		1				12	1111	2734	3866
Gadids (Gadidae)		1	14	2			1	1			19
Herring (*Clupea harengus*)			2	1				63	2373	538	2977
Unidentified	19	859	1350	1545	50	66	3	7375	3095	9774	24136
Total	51	1366	2606	2746	163	143	9	8467	6744	13093	35388

(Olson 1995, 1996, 1999a, 1999b, 2003, 2004, 2006a, 2006b; Olson & Walther 2007) and Vedmora showed some more, but still rather few fish specimens. The predominant species differ somewhat between the sites. Pike (*Esox lucius*) predominated at Sittesta, Högmossen, Vedmora and Hedningahällan, whitefish/salmonids (Coregonidae/Salmonidae) at Fräkenrönningen, perch (*Perca fluviatilis*) at Södra Mårtsbo, and flounder/flatfish (*Platichthys flesus*/Pleuronectidae) and sculpin (Cottidae) at Bjästamon (Olson *et al*. 2008). At Ajvide and Jettböle, on the large islands of the Baltic Sea, herring and cod are most common (Paper I). At Kornsjövägen, with only nine fish specimens, perch was the sole species identified more than once (Table 4). Despite the burnt condition of the mainland fish remains, the identified number of fish species is high. However, a comparison between Neolithic sites of Eastern Middle Sweden with burnt (Högmossen, Fräkenrönningen, and Bjästamon) and unburnt bones (Korsnäs, Äs, and Anneberg) clearly shows that the unburnt assemblages exhibit a markedly higher frequency of fish bones (Figure 5).

The distribution of fish species shows that percids, pike and cyprinids are more common at the southern sites, whereas sculpin and flatfish are predominant in the north, and herring and cod most common at Gotland and Åland. The reliability of this pattern is to some extent confirmed by the unburnt materials of the mainland at Korsnäs, Äs, Åloppe and Anneberg, which also show large amounts of percids, and pike. Cyprinids are abundant at Äs, Åloppe, and Anneberg, but not at Korsnäs (Aaris-Sørensen 1978; Lepiksaar 1974; Hedell 1902 unpubl.; Segerberg 1999). Further north along the coast, there are only burnt materials to compare with.

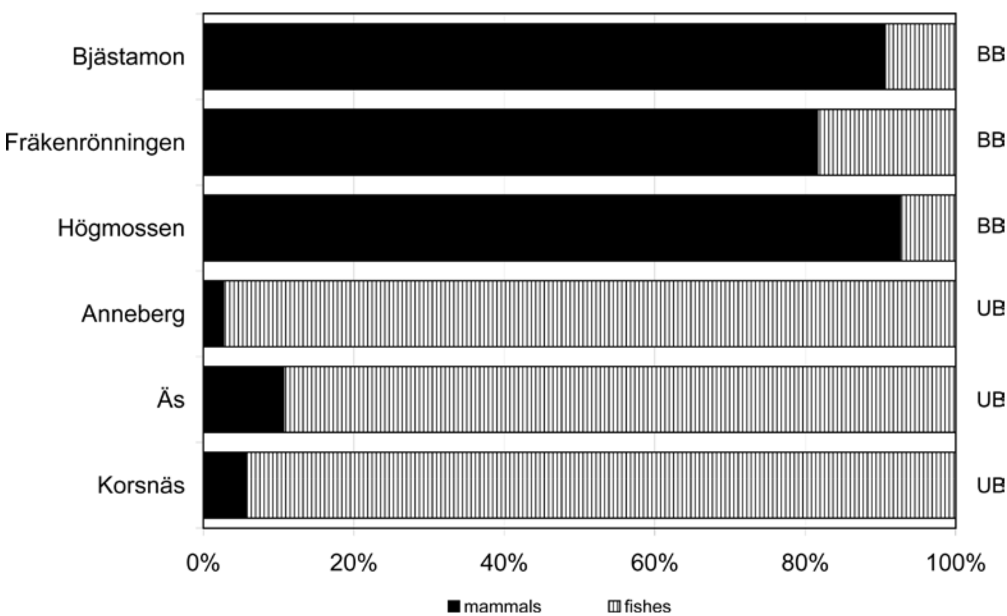


Figure 5. Frequencies of mammals, birds, and fishes of burnt vs. unburnt bones BB = Burnt bones, UB = Unburnt bones

The unique predominance of whitefish/ salmonids at Fräkenrönningen may be compared with the unburnt amount of whitefish at Anneberg (n=407), and the burnt, and relatively large amount (n=221) at the site Dalkvarn 1 in Hälsingland. Sculpin specimens (n=41) were also found at Dalkvarn 1, and at Jättendal (n=70) (Jonsson & Wallander 1993/1994; Holm 2006:81). However, the amount of flatfish found at Bjästamon must be considered exceptional, given that only two more specimens have been found at Jättendal, one at Dalkvarn 1, and one at Kornsjövägen along this stretch of coast. The Neolithic sites within the large river systems connected to this coastal region show no finds of sculpin or flatfish (Ekman & Iregren 1984), which if they were abundant, could have been expected, since they are known (in modern times) to sometimes enter rivers and streams (Pethon and Svedberg 1989; Swedish Board of Fisheries, website information). Today's distribution of fish species is similar to that found during the Neolithic, but Neolithic flounder appears to have been more frequent in the northern part of the area. The Baltic Sea was different in other aspects also. The harp seal was common and the ringed seal showed a more southerly distribution during this period, which is different from today (Storå 2001).

Evidence suggests that fisheries focused on perch at Södra Mårtsbo, pike at Högmossen, whitefish/salmonids at Fräkenrönningen, flatfish and sculpin at Bjästamon, and cod and herring at Ajvide and Jettböle. It is perhaps not surprising that pike dominate the small fishbone assemblages, e.g. those from

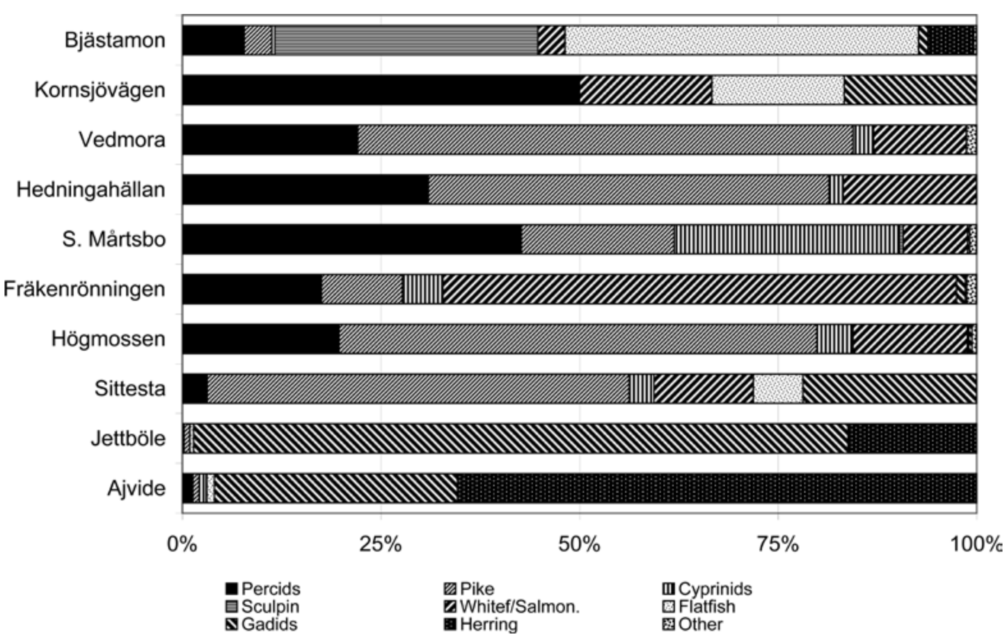


Figure 6. Fish species frequencies at the studied sites based on number of identified specimens (NISP).

Sittesta, Hedningahällan and Vedmora, since the most common skeletal element recovered from pike at those sites is the robust dentary bone. However, pike is also clearly dominant at Högmossen with relatively large amounts of fish remains. This may indicate that pike is still the fishery target, since several other species in fairly large numbers were preserved there. Why pike specimens are relatively few at the northernmost fish frequent site Bjästamon, is difficult to explain or relate to biotope. There is no obvious reason for the low numbers. The low frequencies of pike at Ajvide and Jettböle, where fish remains are numerous, and preservation conditions good, may perhaps be more related to the local biotopes. The different fishery foci based on NISP summary data could indicate local profiles, and even if numbers of fish are low at some sites, the predominant species may still indicate favourable habitat conditions or a preference for consuming these species. The differences between the sites are interesting results (Figure 6). They indicate an obvious variability in the fishing economies along the coastline, they also point to seasonal activities, and probably to a varying ecosystem, and an environment somewhat different from today, which is of fauna historical interest.

Representativeness and quantification

From killing, butchering, distributing, preparing, and consuming to disposing of the leftovers of an animal that was eaten, each step has affected the taphonomic history of the assemblages during the Stone Age (Lyman 1994a; Gifford-Gonzalez 1991). Added to that is the effect of the postdepositional taphonomical processes that further reduce and/or alter the skeletal remains over time (e.g. Noe-Nygaard, 1977, 1987; Lyman1987, 1994a; Behrensmeyer & Hill 1980; Schiffer 1987; Bonnichsen & Sorg 1989; Hudson 1993).

A contextual evaluation of the burnt bone remains from Högmossen, Fräkenrönningen, Södra Mårtsbo, and Bjästamon was carried out by counting species occurrence per context (Paper IV). This reflects the number of times a species has been handled at a site. The contextual quantification offers an additional basis for the interpretation of faunal remains beyond that which NISP data can offer. When seal and fish bones were quantified by their occurrence in contexts the results were somewhat altered compared to quantification by NISP summary data. (Figure 7). Högmossen and Fräkenrönningen showed an increase in fish and decrease in seals, whereas Bjästamon showed almost equal ratios of fish and seal when quantified by either method. In contrast Södra Mårtsbo showed a decrease in fish when quantified in contexts. When only the fish species from these sites were quantified by both contextual and NISP methods a similar pattern was shown. The high frequency species at each site decreased in favour of the low and medium frequency species (Fig. 3, Paper IV)

To some extent the small sample sizes at some sites must be considered. Although there is variation in amount of bone in the different contexts, they often contain bones of only a few fish individuals. Quantification using *minimum number of individuals*, MNI, in burnt materials is complicated. The strong fragmentation affects the possibilities for identification. Another aspect is that vertebrae are the most commonly preserved skeletal elements of fish, and for MNI estimations vertebrae with a clear morphological distinction are needed, e.g. the uppermost, position 1 and 2 of the vertebral column. These are unfortunately not frequently encountered in the materials from the burnt sites of the mainland. Cranial elements are not so common except for

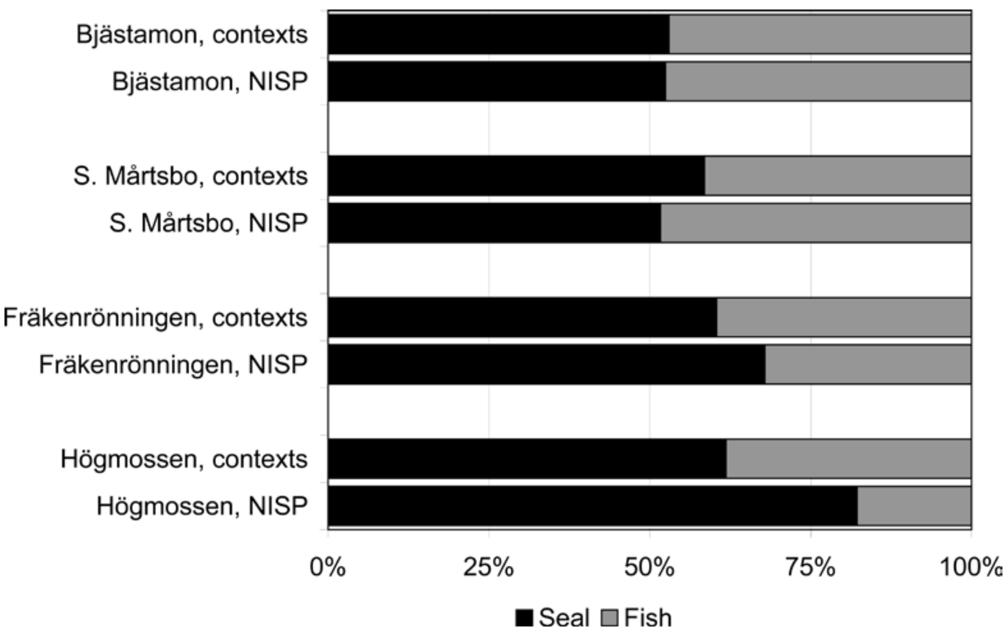


Figure 7. Seal and fish frequencies quantified by occurrence in context and NISP

Table 5. Minimum number of individuals (MNI) of pike in contexts at Högmossen, Fräkenrönningen, Södra Mårtsbo and Bjästamon

Sites	Contexts > 1 MNI	Contexts MNI = 1	Total no. contexts	Total MNI
Högmossen	15	52	67	87
Fräkenrönningen	4	82	86	90
Södra Mårtsbo	17	68	85	117
Bjästamon	1	4	5	6

the robust dentary bone of pike. Most contexts of the studied sites produce MNI estimates of one individual per context, (Table 5). It showed that at most 22 % of the contexts included more than one MNI at Högmossen, the site where pike was the predominant fish species. At Fräkenrönningen only 5 % of the contexts showed more than one pike. At Södra Mårtsbo 20 % exhibited more than one MNI. At Bjästamon there were only 5 contexts with pike, of which one contained 2 individuals. Thus, it seems that bones of a few fish were deposited at the same time. This might explain why the low and medium frequency species appear to be more common in the contextual quantification than the summary data. However, most contexts lack skeletal elements suitable for MNI calculations. The most common species on most of the sites are mainly represented by vertebrae which affects the reliability of the comparison.

6. FISHERIES AND FISHERS

Ecosystem influences on fisheries

The archipelago environment along the Eastern coast of Sweden should more or less have been suitable habitats for the identified fish species from all of the sites. The predominance of certain species at the different sites may, nevertheless, indicate an adaptation of the fisheries to each specific local or regional environment (Paper IV). For example, Fräkenrönningen showed a dominance of whitefish and salmonids, which is not seen at any other site in such large quantities. This indicates close access to riverine estuaries, where the capture preferably would have taken place when these species gathered before the spawning season. Seasonal resources may be important factors for settlement patterns. This might be the case at Fräkenrönningen (Paper V).

The northernmost site, Bjästamon, uniquely showed a predominance of flatfish and sculpin. The presence of these quantities of flatfish and sculpin is unmatched elsewhere, and may indicate Bjästamon's prehistoric proximity to particularly favourable environments for these species, e.g. shallow water lagoons and littoral zones. Moreover, this aquatic environment should have been common along the coastline of the entire area.

The low presence of certain species must also be considered. For example, the low amount and sometimes absence of herring at the mainland sites is surprising, but probably for the most part related to taphonomic processes and recovery methods. An illustrative example to this, and the impact of fine-mesh sieving of soil samples, is the find of more than 21.000 herring bones at the mainland site Korsnäs, which prior to this find showed a predominance of perch. The absence or low numbers of eel is also worth considering, since this species, like herring, should have been accessible within the entire studied area during the Neolithic. The fact that both herring and eel are fatty fishes with skeletons more sensitive to decay than non-fatty species, may to a great extent explain their low frequency (e.g. Lepiksaar 1974; Wheeler & Jones 1989:62). Discarded fish remains that were not burnt could also be a reason for the absence of species at some of the sites. However, the overall high diversity of burnt fish species from the mainland sites contradicts such an explanation. All species seem to be present. A greater representation of flounder, at all sites, except for Bjästamon, and small cod in the large bays of the archipelago may have been expected at the mainland coastal sites. As a comparison the extensive cod and herring fisheries at Ajvide and Jettböle seem to mirror the relative great abundance of these species in the waters around the large islands of the Baltic Sea.

Fish sizes are also related to the habitats they occur in. For example the fairly large sizes of the cod and herring from Ajvide confirm a fishery some distance from the shore, while the smaller cod and herring at Jettböle indicate a fishery in shallower water in the littoral zone (Paper I and III). Here the qualitative aspects of the bones are informative and complement the quantitative pattern. Also, this highlights the possibilities to perform osteometric studies in the unburnt assemblages. The growth patterns of cod indicate that the conditions in the Baltic were different from today (Paper III). This has been observed also for seals. The growth patterns of Neolithic harp seals and ringed seals were different, and they were smaller than today (Storå 2001).

Fish ethology and season of capture

The fishes at the sites represent species of fresh/brackish, migrating, and marine origin. Their characteristic behaviours, spawning habitats and periods of abundance must surely have been well known to the fishers at the sites. Fish species that occur in large amounts at the various sites were plausibly of importance to the settlers. It is more difficult to assess the value of the low frequency species even if the comparison of species in the excavation units indicate that they may have been more common than shown by the summary NISP data (Paper IV). However, all species, high or low frequency, are important seasonal indicators (Table 6). Together with mammals and birds, fishes may aid the assessing of site occupational periods, and whether or not a site could have been used on a year round basis (e.g., Bäckström 2007; Storå *et al.* 2008; Olson *et al.* 2008).

Perch is best caught during spawning which occurs from the ice-run until July, or in general in the warmer periods of the year, when it resides close to the water surface. Pike and pikeperch are most vulnerable to fishing during the spawning seasons when they occupy shallow waters in search of food, pike in early spring and pikeperch later in spring (Nilsson & Smedman, 1994). A good season to catch pike is also during mid fall when it once again enters littoral zones in search of prey (Olsson 1994). In addition to the most favourable season, perch, pike and pikeperch were more or less accessible during the whole year. This is not the case for cyprinids, flatfish and eel, which rest in a state of hibernation in the bottom sediments during the winter period, and are then difficult to find. Sculpin and burbot occupy deep waters during spring, summer and early fall, which makes them easy to catch only during late fall and/or winter when they enter shallow shore habitats (Paper IV). Herring is normally a spring or summer indicator, but could have been available at all seasons of the year as in recent times in the Åland archipelago (Storå 2003). Small cods occupy shallow waters at most seasons of the year. Larger cod are active in deeper waters some distance away from the shore.

In terms of fisheries, most of the larger sites appear to be year round occupations, even if a reliable winter indicator like burbot, for example, is missing at Sittesta, Hedningahällan, Kornsjövägen, and Jettböle. The natural habitat of burbot is in fresh water lakes and in the waters of the archipelago. Nevertheless, a plausible winter indicator at these sites is ringed seal, even if this species could be hunted throughout the year (Storå 2001).

At Ajvide, cyprinids and flatfish indicate a fishery during spring and summer, while the other species were available more or less during all seasons of the year; perhaps herring was mainly captured during the period of spring to late summer. The cod fishery at Ajvide took place in all seasons, but mainly during winter (Paper III), and was thus not focused on the spawning season only. This is interesting and shows that prehistoric fishing patterns are not always predictable by analogy to modern data. Winter fishing for cod at Ajvide probably took place from the ice, like in modern-day game-fishing (Nilsson and Smedman 1994). Cod fishing during other seasons needed watercraft. Various ages of seals at Ajvide also indicate a year round presence and that hunting was carried out in all seasons, even if intensified during breeding in winter/early spring (Storå, 2002). Among the fish species at Jettböle, flatfish is a summer indicator, the other species could be captured in all seasons of the year, including from the ice during winter as in recent times (Storå, 2003). At Högmossen, pike and perch were the most common fish species, best captured from early spring to mid/late fall, but could also have been available during the winter period. Going further north to Fräkenrönningen, the predominance of whitefish/salmonids indicates a fishery during fall when whitefish, and salmonid species gather at the river estuaries before spawning (Pethon & Svedberg 1989; Nilsson & Smedman 1994). This fishery may have constituted the most important protein source when harp seals had migrated south and the best hunting season for ringed seals was yet to come. Similar strategies seem likely at the northernmost site *Bjästamon*, where sculpins, seem to have provided the settlers with proteins during late fall/early winter before the onset of the hunting season for ringed seals (e.g. Broadbent 1979; Huggert 1990; Fandén 1999; Storå 2001). The predominant flounder/flatfish also confirm an important summer fishery at Bjästamon (Table 6).

The diversity of Neolithic fisheries in the Baltic Sea

Abundancies of different fish species varied considerably, shown from several investigations of Neolithic coastal sites around the Baltic Sea. Among the identified fish species from the sites in the Baltic Sea area, percids (mainly *Perca fluviatilis*) predominate, however, mostly due to the large amount found at Anneberg, Uppland, Sweden. Disregarding this specific find, perch would still have been one of the three most common species in terms of NISP, together with herring (*Clupea harengus*) and cod (*Gadus morhua*). Pike (*Esox lucius*) and cyprinids (Cyprinidae) are also frequent at most of the sites, followed by whitefish (*Coregonus lavaretus*) and salmonids (Salmonidae), and then flatfish (*Platichthys flesus* and *Psetta maxima*). Sculpin (*Triglopsis quadricornis* and *Myoxocephalus scorpius*), and eel (*Anguilla anguilla*) occur in almost equal amounts, and dominate over burbot (*Lota lota*) mainly because of the large amounts of bones retrieved at Bjästamon and Rzucewo in Poland respectively. The most common species in terms of occurrence at number of sites is perch, which is present at 26 of 31 sites, followed by pike at 25 sites, followed by cyprinids and whitefish/salmonids at 20 sites. Of the remaining identified fish species, cod was present at 18 sites, flatfish at 16, herring at 13, burbot at 9, sculpin and eel at 7, and sturgeon at 3 sites. The largest amounts of perch and pike have been retrieved from the mainland sites, and these two species together with other fresh water species such as cyprinids, are most frequent in the southern part of mainland Eastern Middle Sweden. Anadromous species such as salmonids and whitefish are more common in the northern part of this area. Cod and herring are in general more common near the large islands, or mainland sites with a direct access to the open sea, like Gotland, the Åland islands, Saaremaa, Estonia and Rzucewo, Poland, than at the mainland sites within a surrounding archipelago (Table 7).

The geographic distribution of fish species from all the Neolithic sites in the Baltic region, shows that herring and cod were uncommon above the 60th latitude (north of Åland), whereas whitefish, salmonids and sculpin were rare below this

Table 6. Spawning periods for the recovered fish species

Fish species	Sittesta	Högmossen	Fräkenrönningen	S. Mårtsbo	Hedningahällan	Vedmora	Kornsjövägen	Bjästamon	Jettböle	Ajvide
Perch	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS
Pikeperch		SS	SS	SS		SS		SS		
Pike	S	S	S	S	S	S		S	SS	S
Roach		SS								
Cyprinids	SS	SS	SS	SS	SS	SS		SS		SS
Burbot		W	W	W		W		W		
Sculpin				FW				FW		
Whitef/Salmon	FW	FW	FW	FW	FW	FW	FW	FW		FW
Eel				SF						SF
Turbot	SS								SS	
Flounder	SS						SS	SS	SS	
Flatfish	SS	SS						SS	SS	SS
Cod, Gadids	SS	SS	SS	SS			SS	SS	SS	SS
Herring			SS	SS				SS	SS	SS

SS = Spring /Summer, SSF = Spring/Summer/Fall, SF = Summer/Fall, FW = Fall/Winter, W = Winter. (Pethon & Svedberg 1989; Nilsson & Smedman1994).

latitude. Perch, pike and cyprinids were most common around this latitude at the mainland coast, but perch and pike were also frequent in the southernmost area of the Baltic Sea, at the Rzucewo site. The distribution probably corresponds well with each local or regional ecosystem. There were no totally unexpected species at the sites, although the amount of flounder/flatfish at Bjästamon was a surprising finding. Also in comparison with unburnt fish remains, the amount of flatfish at Bjästamon is larger than those at Ire on Gotland, Kaseküla in Estonia, and Rzucewo in Poland (Ekman 1974; Lõugas 1997; Makowiecki & Van Neer 1996).

Life in the coastal settlements

The faunal remains, artefacts, remnants of house structures, hearths, refuse heaps, and activity areas all bear traces of the interaction and relation between the people who once lived at a site. It is from the patterns of the leftovers of these people that we may learn more about the lives of the men, women and children who once occupied these settlement sites. To live by the sea was a choice based on the possibilities for subsistence. The rich ecotones that are created in the border-zone between land and sea attracted people to settle down. The conditions for gathering, fowling and fishing were probably favourable and stable. Fishing should have been possible on an everyday basis.

Two middle Neolithic coastal sites in this study that were partly contemporaneous but rather different, on the basis of their fisheries, were Fräkenrönningen at the mainland and Ajvide on Gotland. Fräkenrönningen had a sheltered location with a surrounding archipelago, and Ajvide was located on the shore of the open sea. The fish remains which show a predominance of whitefish and salmonids at Fräkenrönningen indicate a major fishing season during the spawning period for these species in autumn (Paper V). At Ajvide, where herring and cod are most common, the season for herring was probably in spring and summer, as in modern times, while cod was captured mainly in fall and winter, and to a lesser extent during spring and summer (Paper III). Seal hunting was also a main source of subsistence both at Fräkenrönningen and Ajvide. The same seal species were hunted, although ringed seal was more frequent at Fräkenrönningen (Olson 1994; Björck 1998) and harp seal predominated at Ajvide (Storå 2001, 2002). The different fishery focus at the sites implied different fishing technologies and capturing methods, and also a different exposure to risk during capture.

The extensive hook assemblage, together with the numerous cod bones at Ajvide, indicate that hook and line fishing for cod was a well tried fishing technology. The hook assemblage at Ajvide is unique in its size (N>600 hooks), and the homogenous design points to an elaborated strategy for catching medium sized cod (Paper II). There can be no doubt that other fishing gear at Ajvide was equally well developed, e.g. nets for herring captures. One small fragment of a bone fishhook was the only fish implement found at Fräkenrönningen. The fishing equipment mainly used at Fräkenrönningen for

Table 7. Number of identified fish species from Neolithic coastal sites in the Baltic Sea area.

Sites	percids	pike	cyprinids	burbot	sculpin	whitefish/salmonids	sturgeon	eel	flatfish	cod/gadids	herring	fish unidentified	Total NISP	Province/Country	UB/BB
Lill-Mosjön	7	3	1		1	149				1			162	Ångermanl.	BB
Bjästamon	85	38	4	4	362	37			486	13	63	5678	6770	Ångermanl.	BB
Kornsjövägen	3					1			1	1		3	9	Ångermanl.	BB
Jättendal	27	16	5	1	70	8			2				129	Hälsingl.	BB
Dalkvarn I	27	12	59		40	221			2		1	14	376	Hälsingl.	BB
Vedmora	17	48	2	1		9						66	143	Hälsingl.	BB
Hedningahällan	35	57	2			19						50	163	Hälsingl.	BB
S. Mårtsbo	495	199	316	4	3	85		1		1	1	1473	2578	Gästrikland	BB
Fräkenrönningen	220	128	64	16		812				14	2	1350	2606	Gästrikland	BB
Högmossen	100	305	23	3		73			1	2		859	1366	Uppland	BB
Snåret (A)						1						169	170	Uppland	BB
Djurstugan	38	19	18			21						253	349	Uppland	BB
Brännpussen	3	19				3						34	59	Uppland	BB
Postboda 2												272	272	Uppland	BB
Anneberg	24168	4001	3656	28		407		13	1	13	2	42160	74449	Uppland	UB/BB
Starrmossen	71	6	5			10				2		94	188	Uppland	BB
Lindskrog	16	183										310	509	Uppland	BB/OB
Åloppe	3081	628	2756	2							2		6469	Uppland	UB
Äs	8268	987	709	1	35				3		11	na	10014	Västmanl.	UB/BB
Häggsta V,VI	15	55	3			8					1	50	132	Södermanl.	BB/OB
Korsnäs	1463	394	37			13		13	40	8	21746	1817	25531	Södermanl.	UB/BB
Jettböle	7	24							16	2734	538	9774	13093	Åland	UB
Ajvide	48	29	33			18		2	35	1111	2373	3095	6744	Gotland	UB
Ire	25	55	8			10	2		154	3584	2940	na	6778	Gotland	UB
Hemmor										5343		980	6323	Gotland	UB
Gullrum										465		3	468	Gotland	UB
Björkärr	1	1								44		11	872	Blekinge	BB
Loona	6	199			10			3	26	7893			8137	Estonia	UB
Kaseküla	286	42	9			20		46	321	157	2		883	Estonia	UB
Naakamäe	3	3					15		14	11			46	Estonia	UB
Rzucewo	2294	621	96				1	437	444	4952	298	13700	22822	Poland	UB
Sum	40813	8080	7808	60	521	1929	18	515	1547	26350	27980	82302	198652		

BB/UB Burnt/Unburnt Bones (Hedell 1902; Ekman 1974; Lepiksaar 1974; Aaris-Sørensen 1978; Jonsson & Wallander 1993; Wallander 1995; Hårding 1996; Hårding & Olson 2000; Makowiecki & Van Neer 1996; Lõugas 1997; Welinder 1997; Sigvallius 2003; Björck 1998; Björck & Björck 1999; Segerberg 1999; Nilsson 2004; Ytterberg 2005; Holm 2006; Sundström et al. 2006; Olson 1995, 1996, 1999, 2003, 2004, 2006, Bäckström 2007; Björck et al. 2008; Olson et al. 2008; Storå et al. 2008) fishing whitefish and salmonids probably consisted of nets or stationary structures as in recent times (e.g. Ekman 1910:393). The organic material that presumably constituted these devices is of course not preserved. Except for a few birch-bark floats from Ajvide, no preserved fishing implements made of organic vegetable material have been found at any of the other sites either. Nevertheless, well preserved Mesolithic remains of nets and stationary fishing structures, i.e. wicker cages, screens, and pointed stakes to hold up the screens, have been found at several archaeological excavations in Denmark, mostly at Kongemose and Ertebølle sites (e.g. Petersen *et al.* 1979; Andersen 1985; Andersen 1995; Pedersen 1995), and in Scania, Sweden (e.g. Petersson & Olausson 1952; Larsson 1983; Mårtensson 2001), confirming their manufacture and use. In Antrea in Finland a very old net, radiocarbon dated to 9320 B.P. was found. The net, which was made of wicker fiber (*Salix cinerea*), measured ca. 27-30 x 1.3-1.5 meters (Edgren & Törnblom 1992). Remains of nets from the Baltic region have also been found at the Neolithic site Šventoji in Lithuania. These nets were made of linden (*Tilia sp.*) bast (Rimantienė 2005). The Mesolithic settlement Tybrind Vig in Denmark had excellent preservation conditions for organics, and finds included fishing implements such as weirs, nets, net floats, leister prongs that were produced from soft organic materials like wood, plant fibers, bark, etc. (Andersen 1985). The stationary fishing structures and the recovered fish remains in Denmark point to a predominance of passive fishing, that generated catches without the necessity of being present during the catch. Manpower could be spent on other work simultaneously. However, active fishing was also performed, which is indicated by the finds of leisters, spears and hooks. At Ajvide active fishing using a hook and line continued throughout the year (Paper III).

Being a fisher and hunter meant a lot of time spent on obtaining raw-material, manufacturing, and maintaining fishing and hunting equipment. The production of harpoons, spears and leisters of bone or antler, was dependent on land mammal hunting, or trade of bone raw-material, since the morphology of the long bones of seal limits how much of it can be used. The lines for harpoons and fishhooks could have been made of sinews or vegetable material such as bast (Paper II). The manufacture of the stationary fishing devices demanded skills in basketry, and a nearby access to good quality raw-material, such as wicker or hazel-rods (Pedersen 1995). Watercraft was needed for the hunting of pelagic sea mammals like harp seal, and fish species like medium size cod. The finds of two dug-out canoes made of linden tree (*Tilia sp.*) from Mesolithic Tybrind Vig in Denmark, confirm the early knowledge in watercraft construction (Andersen 1985).

The production and maintenance of fishing gear was quite comprehensive work, which possibly involved some kind of organized labour. When Pedersen investigated a number of large stationary fishing structures from Mesolithic to present times (1995), she concluded that, in addition to the functional aspects of the structures, the different sizes of these structures, and then especially the large Neolithic devices, may point to a degree of social complexity within the fishing villages. Also, the analyses of the material used in these structures pointed to an elaborated systematic forest management in the Neolithic, demanding organized labour to maintain the production of raw-material for manufacturing these large stationary fishing structures. What is also closely linked to the use of stationary structures, is the access to the areas where abundant catches could be expected. Therefore, the efforts to maintain these rights must also have been included in the fisheries. A similar interpretation regarding seal hunting with nets along the Bothnian coast during the Stone Age was suggested by Broadbent (1979).

Fishing territories and the right to the fishing grounds must have been essential to the dwellers in areas with many contemporaneous sites, as in coastal Middle Sweden, and on Gotland and Åland. In medieval and recent times in the Åland islands, the fishing rights were complicated matters, depending on a number of reasons related to land territory rights, the kind of fishery that was regarded, personal rank or status, rules by the crown etc. (Storå 2003:34-53). Fishing rights in traditional societies also have a number of rules that are expected to be followed. There are examples from fishers in Oceania of the South Pacific where the chiefs, clans, or villagers of the islands by custom owned the rights to fish in designated areas, and also had the rights to exclude others from fishing there (Johannes, 1984). Many native Californian tribes had territory rules including the defence of the well-defined boundaries of each village-owned shore tract, while there were also special agreements to share certain subsistence resource areas (e.g. Gould, 1978; Pilling 1978; Wallace 1978). We cannot know what restrictions and permissions were valid at the Neolithic coastal sites, but the access to high yield fishing grounds must have been essential.

Included in the strategies of maintaining a fishery as a basis for subsistence, and as part of the daily life in a coastal foraging society, technology, social organization, ideology and environment must interplay. Any changes that may occur within these intertwined factors will always have an impact on the other parts of the interplay. If, for example, a more efficient fishing technology, with new fishing tools were introduced, this would most likely demand a reorganization and a rethinking of the resource strategies (Storå 2003). There is a complexity within the coastal settlements that is difficult to comprehend and to deal with. We may never fully understand these societies. Nevertheless, a complexity fortunately also involves many different issues still to be investigated, and only a continuous research will lead us closer to the life ways of the fishers, hunters and gatherers of the Neolithic.

To approach prehistoric peoples' social life, ideology and communication is extremely difficult, but a glimpse of their daily life and rituals is shown by the archaeological finds. Here, the production and maintenance of fishing implements confirm, apart from the well developed fishing strategies, and skilled craftsmanship, that fishing was, to a large extent, on the peoples' minds, even when not fishing (Figure 8).

Figure 8. Potsherd with fish ornamentation from the Pitted Ware Site Fräkenrönningen, Gästrikland. Reprinting permitted by Länsmuseet Gävleborg (Gävleborg County Museum)

7. CONCLUDING REMARKS

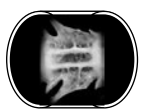
From what we have seen, the Neolithic period supported in general a variety of fisheries. The people at Ajvide on Gotland and Jettböle on Åland primarily captured herring and cod. The cod were larger in the waters around Gotland than in the the Åland archipelago. The herrings were also larger at Ajvide, but showed two separate size-groups, with the smaller herring of similar size to the smallest sizes at Jettböle. The fisheries on the mainland had somewhat different targets. Sittesta, Högmossen, Hedningahällan and Vedmora displayed a predominance of pike. At Fräkenrönningen whitefish and salmonids were most frequent. Perch was predominant at Södra Mårtsbo and Kornsjövägen, while flounder/flatfish and sculpin were most common at Bjästamon.

The different fisheries may be the outcome of an adaptation to spawning periods in local or regional ecosystems. All sites are not contemporaneous, and the fast changing environment, due to isostatic uplift and altering shore lines may have had a strong impact on the biotope. Still some of the differences may have had other reasons. The fish assemblages from Ajvide and Jettböle are unburnt and well preserved. The bone material from Sittesta was both unburnt and burnt and rather poorly preserved. The faunal assemblages from the other sites had only preserved burnt and strongly fragmented bones. The amount of burnt fish remains was markedly lower when compared to the unburnt assemblages from the mainland, such as Korsnäs, Äs, Åloppe, and Anneberg.

A contextual quantification method was evaluated against NISP summary data. This method is applicable to bone material from large-scale excavated sites with documented excavation units, contexts and features. It showed that the bones of the low and medium frequency species were deposited more often than NISP data indicate.

The fishhook technology at Ajvide was thoroughly examined by manufacturing two sets of replicas that were strength-tested, and almost 400 hooks from the Ajvide assemblage were also subject to a number of measurements and breakage studies. It showed that the Ajvide hook assemblage was rather homogenous, and had a static weight-bearing capacity greater than the average Ajvide cod. The sizes of the cod and hooks pointed to a specialized fishery in rather deep water some distance out from the shore of Ajvide.

Seasonal studies of Ajvide cod otoliths showed that most cod were captured in the winter period, at an average age of four (years old). Notable is that the Ajvide cod were not primarily caught during the spawning period. Also the specific size/age focus at Ajvide, which targeted less productive cod instead of more productive larger, older cod, must have been positive for the dynamics of the marine ecosystem. The Baltic cod was different; cod lived under other conditions than today, which is evident in the growth patterns. In comparison to modern cod, the Ajvide cod grew faster the first years of life, but grew to smaller asymptotic lengths.



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