CHAPTER TWO

VIKING AGE ECONOMICS AND THE ORIGINS OF COMMERCIAL COD FISHERIES IN THE NORTH ATLANTIC

Sophia Perdikaris and Thomas H. McGovern[1]

The origins of commercial fishing: old problems and new insights

This paper presents the results of sustained investigations in Iceland over the past two decades, which have produced large archaeofauna from both coastal and inland sites dating from the ninth to the nineteenth centuries. It seeks to place these collections in the wider context provided by new inter-regional syntheses and to present a series of analytical approaches to understanding patterning within fish-dominated archaeofauna. A multi-indicator approach is applied to the complex issues of distinguishing fish consumer and fish producer sites, and the still more complex problems of distinguishing probable subsistence production from possible market production on coastal sites.

Nearly a decade of investigation of Viking-age inland sites around the highland lake Mývatn in northeastern Iceland has produced archaeofauna rich in domestic mammals and freshwater fish, but also containing significant amounts of apparently preserved salt water fish.[2] Work in the West Fjords of northwestern Iceland has produced fish-rich archaeofauna

[1] We would like to thank the many scholars who have so kindly provided practical assistance, data, and sound advice in the field and in the laboratory, both in the US and in Europe. We would also like to thank the many student assistants who contributed to the laboratory analyses, particularly Colin Amundsen, Yekaterina Krivogorskaya and Konrad Smiarowski. The REU students especially Hugo Asurza, Dmitri Chitov, Olexandr Volkov, Eduardo Martinez, Courtney Scott and high school students Shaye Storm and Elina Melamed. Support has been generously provided by the US National Science Foundation (Office of Polar Programs Arctic Social Sciences and Anthropology Programs), the Icelandic Science Council, the National Geographic Society, the PSC-CUNY grants fund, CUNY Northern Science and Education Center, The Claire and Leonard Tow named professorship, and the Leverhulme Trust Landscapes circum Landnám project. This paper is a product of the North Atlantic Biocultural Organization (NABO) research cooperative.

[2] McGovern, Perdikaris *et al.* (2001); McGovern *et al.* (2005).

from coastal sites (both classic deeply stratified farm mounds and shallow seasonal fishing stations) dating (from the twelfth to the nineteenth centuries).[3] These sites have all been comparably excavated (stratigraphic excavation with 100 percent sieving) and recorded into a common data management system,[4] and provide the basis for systematic comparison between archaeofauna. Thanks to the support of the Leverhulme Trust's *Landscapes Circum Landnám* project,[5] a series of radiocarbon dates and Carbon and Nitrogen isotopic assays are also now available for Viking-age human and animal burials in the inland Mývatn region, providing a check and supplement to the (zooarchaeological) evidence.

This Icelandic work is placed against a background of comparable archaeofauna from elsewhere in the North Atlantic, and this paper has been particularly inspired by synthetic work by James Barrett and his collaborators.[6] Barrett and his co-workers have recently made use of all available datable British archaeofauna to define a surprising but convincing 'fish event horizon' of c. AD 950–1050).[7] Prior to this temporal and spatial horizon, marine fish-bones are virtually absent on any inland site in Britain, and the dense 'fish middens' documented by many workers in Northern Scotland and the Northern Isles also seem to post-date the horizon. The 'fish event horizon' appears as an archeological event horizon (constrained at present by the limitations of radiocarbon dating) without evidence of a gradual local process of development. There is an emerging consensus among workers active in the Hebrides, Orkney, and Shetland that deep-sea marine fishing intensified with the arrival of the Scandinavians, and that the Celtic peoples of the Northern and Western isles were probably not engaged in large scale deep sea fishery during the later Iron Age.

This zooarchaeological pattern is also reflected in the far more terrestrial isotopic signatures of the bones of pre-Norse island human populations, which suggests a significant increase in seafood consumption following the Scandinavian settlement.[8] It thus appears that large-scale production and exchange of dried fish did not originate within the British Isles. Any evidence for extensive exchange between coastal

---

[3] Amundsen (2004); Amundsen *et al.* (2005); Edvardsson *et al.* (2004; 2005); Krivogorskaya *et al.* (2005).

[4] NABONE 8.0. Perdikaris *et al.* (2004).

[5] Edwards (2004).

[6] Barrett (1997; 2000; 2001; 2004; 2005; this volume).

[7] Barrett, Locker and Callum (2004; this volume).

[8] Barrett *et al.* (1997; 2001); Cerron-Carrasco (1998); Nicholson (1998).

and inland sites elsewhere in the North Atlantic/North Sea region prior (to c. 1000) becomes particularly significant. One potential source for the fish event horizon in Britain and the general expansion of marine fishing in the eleventh-early twelfth century are the Scandinavians.

The Scandinavian connection?

Fishing, hunting of sea mammals and sea birds, and the collecting of shellfish and sea-bird eggs were all features of Scandinavian subsistence economies far back into prehistory. Most Nordic farmers of the later Iron Age probably spent as much time aboard a boat as behind a plough, and the notion that Scandinavian coastal subsistence economies stood upon 'one green foot and one blue foot' is well established in Nordic archaeology.[9] The investigation of the interaction of marine and terrestrial economies remains an important regional research topic that is now attracting the sustained attention of several interdisciplinary, international research programs.[10] Even for inland settlements in Atlantic Scandinavia, the sea remained the lifeline of northern existence, with seals, seaweed, sea-bird eggs and marine fish travelling many kilometres from the shore.[11]

During the Viking age (traditionally c. 750–1100), Scandinavian peoples and their dual maritime/terrestrial economies expanded into northern Europe, and populated the offshore islands of the North Atlantic, briefly reaching North America by the year 1000. Viking age society was strongly competitive, and chieftains employed war, piracy, 'protection racket' threats (Danegeld), and the control of distribution of both staple and more prestigious goods to attract and hold followers both in the ancestral homelands and in the new lands of the Atlantic expansion.[12] A key element for these expansionist movements and the subsequent accumulation of wealth was intensive marine fishing and the production of air-dried cured fish.[13] This staple product could be stored for five to seven years without salt or refrigeration, and provided a source of light, portable, and highly nutritious protein to provision farm households, travellers, boats, crews, and marauding raiders.

[9] Bertelsen (1991).
[10] McGovern (2004); Edwards *et al.* (2004).
[11] McGovern (1985); McGovern, Perdikaris *et al.* (2001), McGovern *et al.* (2005).
[12] Vésteinsson *et al.* (2002); Perdikaris and McGovern (2005).
[13] Perdikaris (1999).

While a range of preservation methods were used, the two most common products were 'stockfish' (air dried in the round, with most of the vertebral column left in the finished product) and *klipfisk* (air dried as a flattened product, with the upper thoracic and precaudal vertebrae largely removed along with the head). Stockfish production is possible only where temperatures fluctuate around the freezing point for months at a time, and strong winds aid the freeze-drying process. The Lofoten and Vesterålen islands in arctic Norway have ideal environmental conditions for winter stockfish production, and have produced some of the earliest archaeological evidence for intensive stockfish production, extending back to the early Iron Age.[14] *Klipfisk* can be produced under a wider range of temperatures, sometimes being dried simply by being spread over beach cobbles. Stockfish and *klipfisk* can be produced from a range of white- fleshed (non-oily) fish, but the cod family (gadid) fish have traditionally been the main species used. Stockfish are best made from individual fish between 60 and 110 cm in live length, while *klipfisk* are best made from fish around 40–70 cm in live length.[15]

From the twelfth century onward, there is abundant historical documentation for the large- scale production of stockfish from the Lofoten and Vesterålen islands, and the commercial-scale production of both stockfish and *klipfisk* from the Orkneys, Shetland, and (by c. 1250) from Iceland.[16] By the high Middle Ages, the preserved Atlantic fish trade underwrote much of the mercantile life around the North Sea and the Baltic, and fish production was standardized into strictly graded named categories. The naturally variable product of a prehistoric fishery along with the prehistoric local social networks of exchange that were embedded in the cultural context of multi-stranded interactions between individuals, lineages, and localities was transformed into a socially disembedded, standardized, uniformly graded commodity which could now play a wider economic role. Now dried fish had been transformed from a variable local product of local artisanal fishers into a commoditized economic abstraction to be bought, sold, and borrowed against by prosperous men in counting houses far from the windy beaches where fish were landed and butchered.[17]

[14] Perdikaris (1996; 1998).
[15] Perdikaris (1999).
[16] Nielssen (1994); Nielssen and Christensen (1996).
[17] Gade (1951).

This historical cod trade of the twelfth century and after is well known, but far less well understood are its origins. Where and when did a transition take place from an ancient artisanal fishery run by local chieftains to a new proto-capitalist international commercial fish trade? Contemporary documentary references to fishing before the twelfth century are rare. The colourful Icelandic sagas (written down 200–300 years after the close of the Viking age) cheerfully ignore most issues of daily subsistence in favour of dialogue and character development,[18] and the medieval Icelandic Grágás law code[19] barely mentions the fish whose bones had already become the single most common object dumped onto contemporary midden heaps. It is up to archaeology and environmental science to illuminate the early history of the cod trade, and the critical transition from a local to a global product.

Fortunately, the past three decades have seen a dramatic expansion in environmental archaeology in the North Atlantic area, with major projects ranging geographically from North Cape to Greenland and extending from the pre-Viking Iron Age down to the early modern period of known commercial fisheries.[20] Major analytical advances have also been made in the identification and quantification of fish-bone assemblages, and common standards of recovery, identification, and data management have been broadly achieved. Excavated fish-bone collections now routinely number in the hundreds of thousands of identified specimens, most from contexts well dated by radiocarbon and volcanic tephra as well as artefact association. These data sets are increasingly being integrated into regional syntheses which, for all their inevitable limitations, are producing some clear and unexpected patterns. International collaboration has been advanced by organizations like the *International Council for Archaeozoologists Fish Remains Working Group* (ICAZ FRWG) and the *North Atlantic Biocultural Organization* (NABO) cooperative.[21] These groups have taken the problem of the commercialization of fisheries as a major research topic, and it seems clear that the cooperative research resulting has now produced some significant breakthroughs.

---

[18] Fridriksson and Vésteinsson (2003).
[19] Dennis *et al.* (1993).
[20] Amorosi *et al.* (1996); Amundsen *et al.* (2003); Barrett *et al.* (1997; 1999); Bigelow (1984; 1985); Cérron-Carrasco (1994); Church *et al.* (2005); Dockrill *et al.* (2001); Edvardsson *et al.* (2004); Enghoff (2003); Jones (1991); Nicholson (1998); Ogilvie (1996); Rackham (1996); Simpson *et al.* (2000).
[21] McGovern (2004).

The Icelandic sites and contexts

Marine fish and sea mammal bones have been found in ninth-eleventh century archaeofauna over ten km from the sea in southwestern Iceland (Reykholt, Háls),[22] in Aðalból and Hakonarstaðir in the eastern interior,[23] and in Granastaðir in northern Iceland.[24] Currently, the greatest concentration of inland sites with marine species present that are datable by tephra and radiocarbon to around the ninth and tenth centuries are in the lake Mývatn region of the north-eastern highlands (50–70 km from the sea, 200–300 m above sea level).

Figure 1 presents a summary of the marine species found in these inland archaeofauna, demonstrating the range of marine mammal, seabird bones and bird eggshells,[25] and fish remains found on these sites. The common mussel has been recovered from several inland sites, but the individuals are tiny (one cm and smaller) and are probably the result of seaweed collection transported inland, as mussels of this size are regularly contained within the root balls of the *Laminaria* sp. kelp washed on shore in many parts of Iceland.

At present, our earliest archaeofauna from coastal sites actively engaged in marine fishing come from the northwestern peninsula of Iceland (West Fjords), a region now the target of several ongoing research projects.[26] The earliest twelfth-thirteenth century context is from the earliest contexts[27] at the site of Akurvík, a stratified series of seasonally occupied small 'booth' structures with associated midden spreads around them. The upper contexts at Akurvík are radiocarbon dated to the mid-fifteenth century, and eustatic uplift seems to have caused abandonment of this seasonal station before early modern times.[28] While this site is not directly contemporary to the earlier ninth-eleventh century collections from inland Iceland, it provides a useful case for comparison, as we can be reasonably certain that it was in fact a

[22] Olafsson *et al.* (2005).
[23] McGovern (1982); Amorosi (1996).
[24] Einarsson (1994).
[25] Identification by Dr. Jane Sidell, University College London.
[26] Edvardsson (2005); Edvardsson and McGovern (2005); Krivogorskaya *et al.* (2005a).
[27] All based on bone collagen from domestic mammals showing fully terrestrial delta 13C; for detailed discussion of the dating of the Mývatnssveit sites see McGovern *et al.* (2005).
[28] Amundsen *et al.* (2005); Krivogorskaya *et al.* (2005b).

specialized seasonally occupied fishing station rather than a year round farm mixing subsistence with market production.

The Lake Mývatn region (*Mývatnssveit*) straddles the Mid-Atlantic rift, and has been volcanically active for thousands of years. Lake Mývatn, a broad shallow lake, has a complex ecology that supports the vast population of chironomid and simuliid flies that provide its name ('midge lake') as well as sticklebacks and arctic charr (*Salvelinus alpinus*). The lake is fed by underground channels, and the major drainage is the river Laxá flowing northwards to the sea approximately 60 km away. The Laxá is a famous brown trout (*Salmo trutta*) stream and in its lower reaches also receives migratory Atlantic salmon (*Salmo salar*), which do not reach the lake area. The whole region has undergone profound environmental change since human settlement in the late ninth century, when the interior deserts were probably at least partially wooded, the wet meadows south of the lake were more extensive, and the low lying valleys probably supported dense stands of birch and willow, now almost entirely cleared. The Mývatnssveit archaeofauna come from five sites (Hofstaðir, Sveigakot, Hrísheimar, Selhagi, Steinbogi) located around the lake, and the Kráká and Laxá rivers that form part of its drainage. The sites are dated by a combination of artefact typology, AMS radiocarbon (currently a total of 39 dates on archaeological contexts), and volcanic tephra. Figure 3 presents the calibrated range distributions for the samples associated with the midden contexts discussed in this paper and for some of the pre-Christian burials.

Hofstaðir was a chieftain's farm in the tenth-early eleventh century and is archaeologically known for its huge long hall (the second largest in Europe after Borg in the Lofoten in Norway) and an associated complex of buildings. The Hofstaðir Viking age archaeofauna (NISP[29] = 8,681) is grouped into two phases (AU) by radiocarbon and tephra. The site has remained occupied down to the present. Sveigakot is a small farm that was founded in the late ninth century (basal midden deposits rest directly upon the 'Landnám' Veiðivötn tephra now dated 871 +/− 2 by the GISP2 ice core, Gronvold *et al.* 1995, Sveinbjornsdóttir *et al.* 2000). It underwent at least two phases of abandonment and reoccupation (on a steadily declining scale) before being finally abandoned in the late twelfth century, and its major archaeofauna (NISP = 14,513)

[29] NISP = Number of Identified Specimens, a count of identified animal bones from archaeological sites. See Grayson (1984).

Fig. 1. Marine species found on sites in Iceland more than ten km inland. Note that clam shells and pieces of great whale bone are excluded due to their use as artifacts and raw material. Atlantic salmon are included for the Mývatn area, as their migration does not extend upriver within ten km of the lake.

Table 1 Taxon		site Adalbol	Hakonarst.	Reykholt	Háls	Granast.	Hofstaðir	Sveigakot	Hrísheimar	Steinbogi	Steinbogi
Sea Mammals											
Phoca vituluna	Harbor seal						1				
Phocidae sp.	Seal sp.			3	1		7	2			
Small Cetacean	Small whale/porpoise							1	1		
Marine Birds											
Alca torda	Razorbill						1			1	
Fratercula arctica	Puffin		1				1				
Uria sp.	Murre or Guillemot						10			3	
Alle alle	Dovkie						2				
Larus sp.	Gull sp.						6	2			
Phalacrocoridae sp.	Shag or Cormorant						2				
Somateria mollissimus	Eider duck						2				
Uria sp. Egg Shell											

Marine Fish											
Gadus morhua	Atlantic Cod	1	1		1	80	372	193	4	51	11
Melanogr aegl.	Haddock					12	231	69	17	11	10
	Ling					1		15		1	
Pollachius virens	Saithe						26	64	9	8	
Brosme brosme	Cusk						3				
Gadidae	Gadid family fish			20		6	592	318	32	95	3
Hippoglossus sp.	Halibut sp.						3				
Selachii sp.	Shark sp.					1					
Anarcharias lupus	Wolf fish						3				
Heterosomata sp.	Flat fish sp.						1				
Salmo salar	Atlantic salmon						3	1	19		
Mussels											
Mytilus edulis	Mussel						32	6	13		
Bird Egg Shell											
Uria sp.	Murre or Guillemot						present				
Procillaridae sp.	Shearwater sp.									present	
total NISP		987	124	48	136	1,656	8,681	14,513	2,949	875	1,302
% Marine		0.10	1.61	47.92	1.47	6.04	14.95	4.62	3.22	19.43	1.84

Fig. 2. Location map of inland sites dating to the ninth-eleventh century with marine species present and the location of the Akurvík fishing station used for comparative purposes.

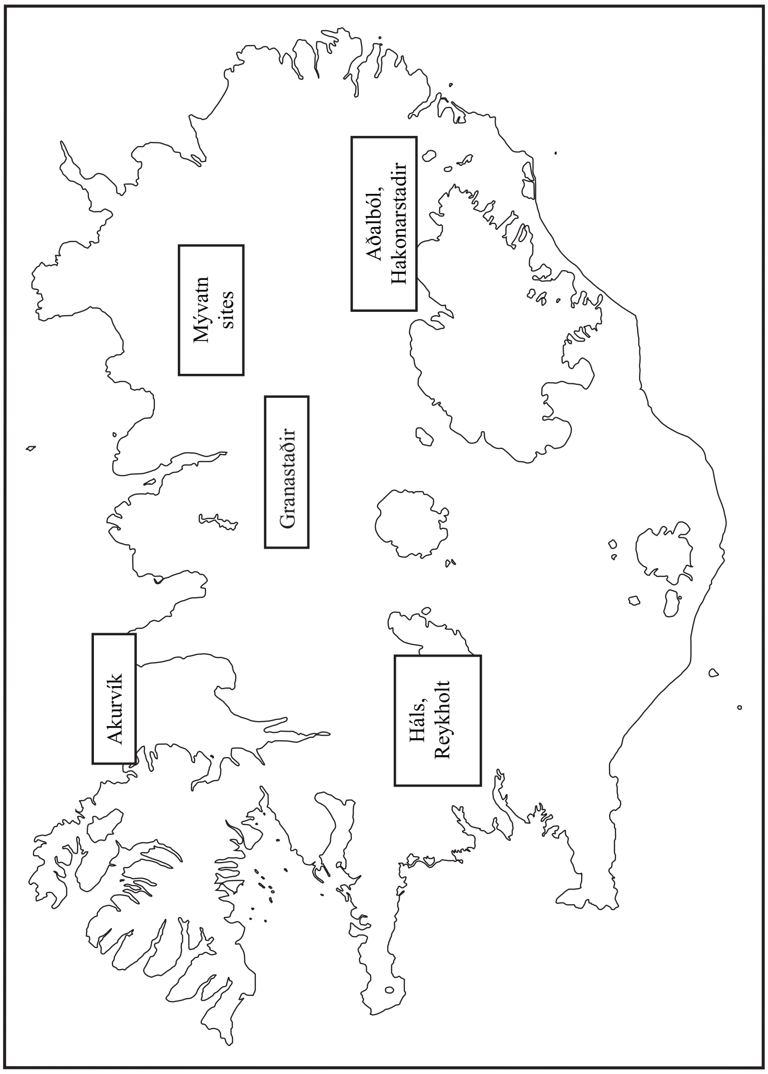
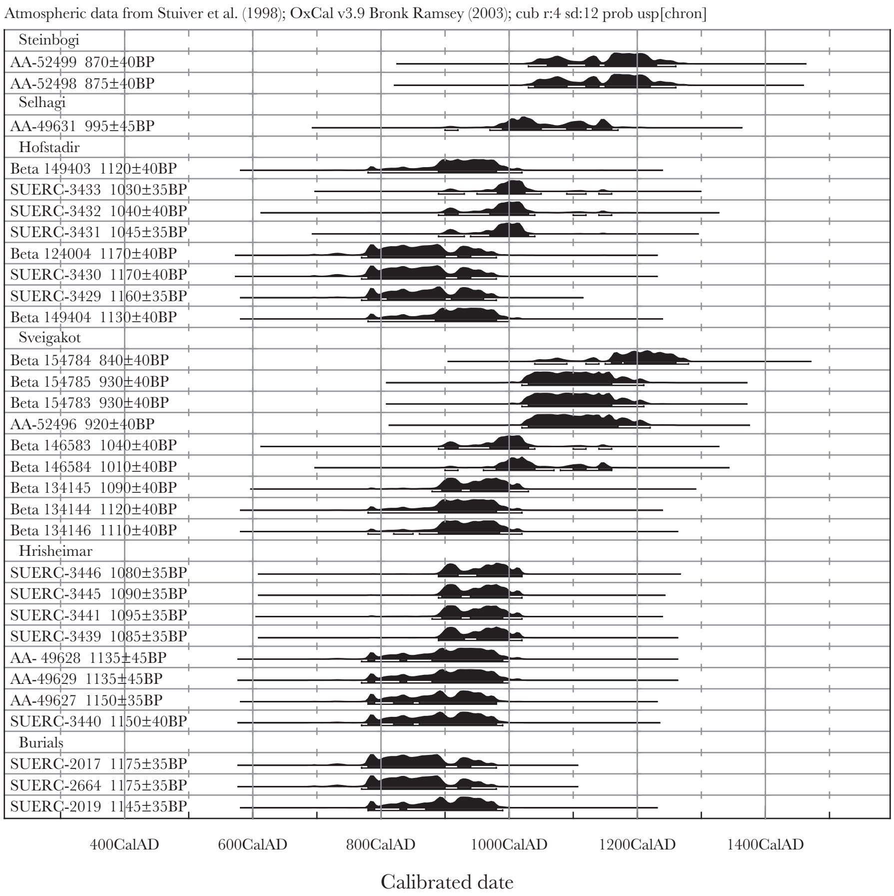


Fig. 3. Mývatn area Calibrated Radiocarbon Dates on midden deposits and burials (fully terrestrial delta C13 only), arranged by site in stratigraphic order. Pre-christian burials make use of horse bones. All contexts dated from Hrísheimar, Sveigakot, Hofstaðir, Steinbogi and Selhagi contained marine fish bones: apparently pre- and post-dating the ca AD 1000 Fish Event Horizon in Britain. OxCal v 3.9 Bronk-Ramsey (2003).



can be grouped into three phases spanning the late ninth to eleventh centuries. Hrísheimur was a substantial site apparently specializing in iron smelting as well as extensive pig keeping.[30] Hrísheimar is still under excavation and its very large archaeofauna is thus presented here in a preliminary form (NISP = 2,949) but the site appears to have been settled shortly after the Landnám tephra and was abandoned prior to the fall of the Hekla AD 1104 tephra.

Radiocarbon dates from the contexts reported here consistently cluster in the tenth century (figure 3). Selhagi is a small site on the lakeshore, with a deep midden deposit extending from the ninth to thirtheenth c. This archaeofauna is the smallest reported here (NISP = 875) and has been omitted from some comparisons requiring larger sample size. Steinbogi is a small site founded in the tenth century and abandoned by 1300. Its archaeofauna comes from a single phase datable to the early thirtheenth c, representing the latest of the Mývatnssveit archaeofauna reported here (NISP = 1,302). The Mývatnssveit archaeofauna thus come from a variety of localities within the highland lake basin and come from sites of varied economic and social status.[31]

Multi-Indicator approach: commercialization signatures

The problems associated with identifying an undocumented pre-commercial, pre-historic, pre-'fish event horizon' pattern of fish distribution and exchange are considerable, given that fisher folk traditionally tend to eat their catch as well as market it, blurring the archaeological record. In the past, different indicators have been used to assess probable commercialization in the zooarchaeological record, ranging from simple abundance of fish-bones in an archaeofauna to more sophisticated arguments based on element representation and differential transport of body parts. A multi-indicator approach combining species diversity, skeletal element distribution, size reconstruction, and age assessment is suggested as a productive way forward, and will be employed in this paper.

[30] Edvardsson (2005).
[31] See Perdikaris (1998) for a detailed methodological discussion.

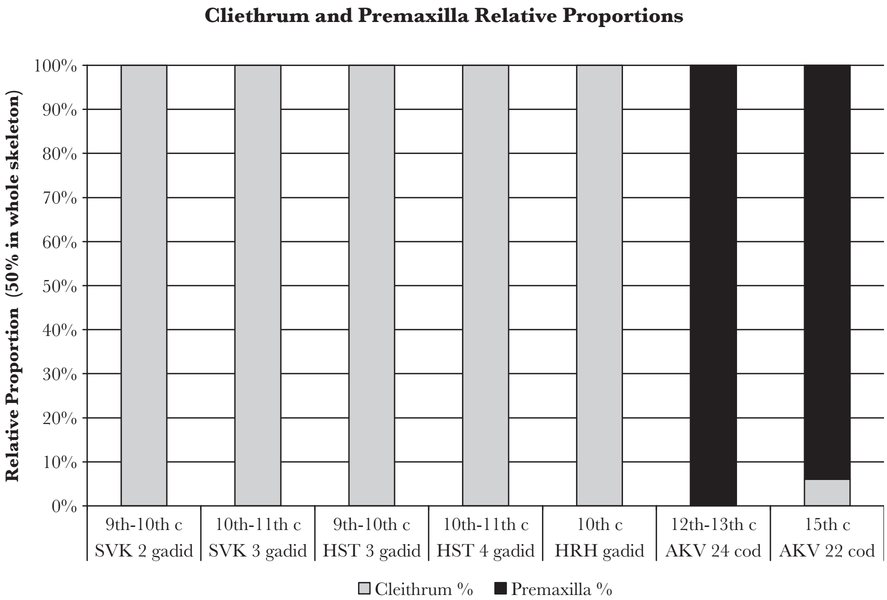
Producers and consumers: selected element distribution

Since fish spoil rapidly, prompt processing has been a key to maintaining seafood quality. Initial butchery tends to take place either at sea or directly upon landing the catch. Fish elements cut away and discarded in preparing fish for consumption or preservation thus tend to accumulate at or near the landing point. From a zooarchaeological standpoint this tends to create a 'producer signature' in the relative abundance of fish skeletal elements excavated. Typically, most of the skull and mouthparts are cut off and discarded at the same time the fish is gutted. Depending on the method of preservation employed, a variable portion of the fish vertebral column is also stripped out and discarded at the processing point. The remaining parts of the skeleton stay with the final product, and may be transported off site to distant consumers. For gadid fish, the crescent shaped cleithrum and associated bones of the pectoral girdle are usually left in the finished product, as these elements help to hold the body together and when spread can help speed drying of the body cavity. Thus a producer site will be disproportionately rich in cranial bones and upper vertebrae, while a consumer site should show a complementary concentration of lower vertebrae and cleithra.

Figure 4 presents the relative abundance of two indicator elements, cleithrum and premaxilla (part of the upper jaw structure), in our Icelandic sample of inland and coastal sites. If only whole fish were present at either coastal or inland sites, the proportions of these paired bone elements would be identical (as each fish has two cleithra and two premaxillae, the graph of a whole skeleton would show an even division of 50 percent each). Both bone elements are of comparable size and durability, both should be comparably subject to the same natural forces of decay and attrition and both can be reliably identified to species level. Thus the relative proportion of these two bone elements should mainly reflect past fish cutting decisions and the effects of differential deposition and transport. It is remarkable that no marine fish jaw parts whatsoever are present in any of the inland Mývatn archaeofauna, and that a clear surplus of mouthparts (or deficit of cleithra) is evident on the coastal producer sites.

Despite such clear patterning, it is somewhat dangerous to base arguments upon only two skeletal elements, and a broader-based approach grouping all the identified fish-bone elements into body areas may provide a stronger basis for comparison. Figure 5 presents a comparison of head and mouthparts, pectoral girdle (cleithrum and associated bones)

Fig. 4. Comparison of the relative proportions of cleithra (bones around the gill slits which tend to travel with preserved fish) and the premaxillae (jaw parts which tend to concentrate on coastal sites). The inland Mývatn area sites (SVK= Sveigakot, HST= Hofstaðir, HRH= Hrísheimar) contrast strongly with the patterning of the coastal seasonal fishing station at Akurvík (AVK). While this graph compares only the larger archaeofauna, it may be noted that no marine fish premaxilla has yet been recovered from *any* inland Icelandic site dating to the ninth-eleventh century. Deposit of whole fish on sites would tend to produce relative proportions close to 50% each.



and the three portions of the vertebral series (thoracic, precaudal, and caudal vertebrae), all normalized for their natural frequency in the gadid skeleton.[32] This figure compares both phases at Akurvík with both the inland Mývatnssveit sites (Hofstaðir, Hrísheimar, Sveigakot, Steinbogi) and the inland site of Granastaðir to the east of Mývatn. In this comparison, it is clear that a few bits of fish skull were reaching the inland consumers (all in the back portion of the skull, none from the front end), but the dominance of the pectoral girdle is clear. Also evident is the abundance of caudal (tail) vertebrae relative to upper body vertebrae in the inland site archaeofauna.

32 MAU%. See Grayson (1984) for discussion.

Fig. 5. Relative proportions of major skeletal groups in the fish body, again comparing sites from inland (Sveigakot, Granastaðir, Hofstaðir, Hrísheimar, Steinbogi) with the coastal fishing station at Akurvík. By making use of all identifiable bones of the fish skeleton this analysis avoids some potential sampling problems associated with singe-element comparisons, but still provides the same clear-cut distinction between inland consumer and coastal producer sites.

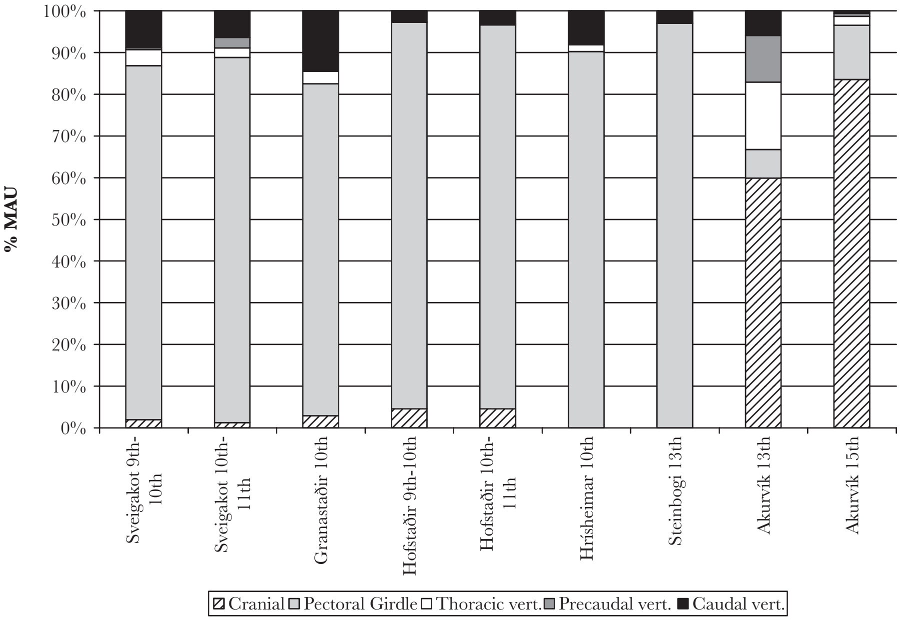
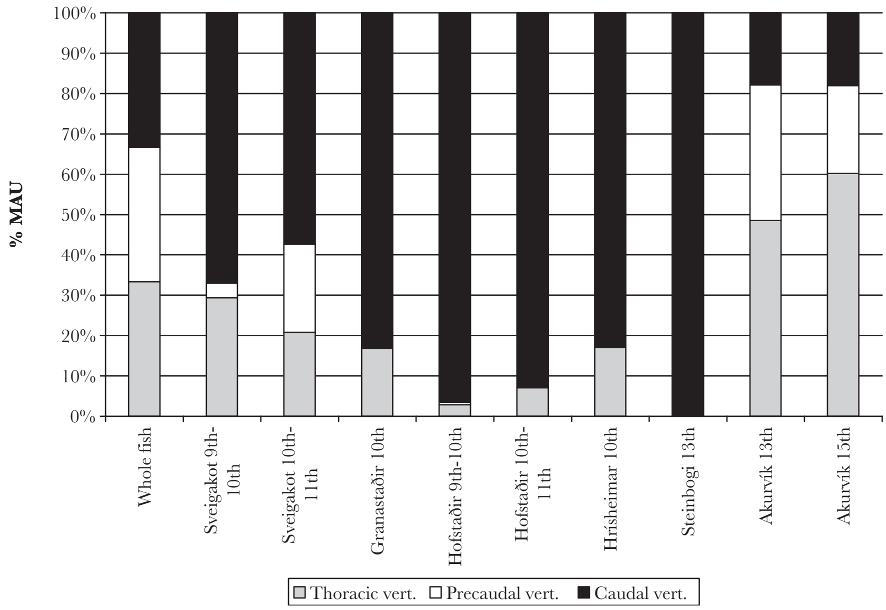


Figure 6 provides a more detailed view by comparing only these vertebral elements for the inland marine fish for the inland Mývatn sites and the two phases of the Akurvík fishing station (again normalized for relative frequency in the skeleton—a whole fish skeleton would have equal proportions of all three vertebral types). The coastal Akurvík vertebral distribution reveals that some fish (smaller individuals) were being deposited whole, with caudal vertebrae intact; these are probably the remains of the fishing crew's meals. However, the coastal fishing station produces a notable surplus of thoracic and precaudal vertebrae, suggesting that the station was producing a product like klipfisk as well as stockfish in both twelfth-thirtheenth centuries and mid fifteenth century.[33]

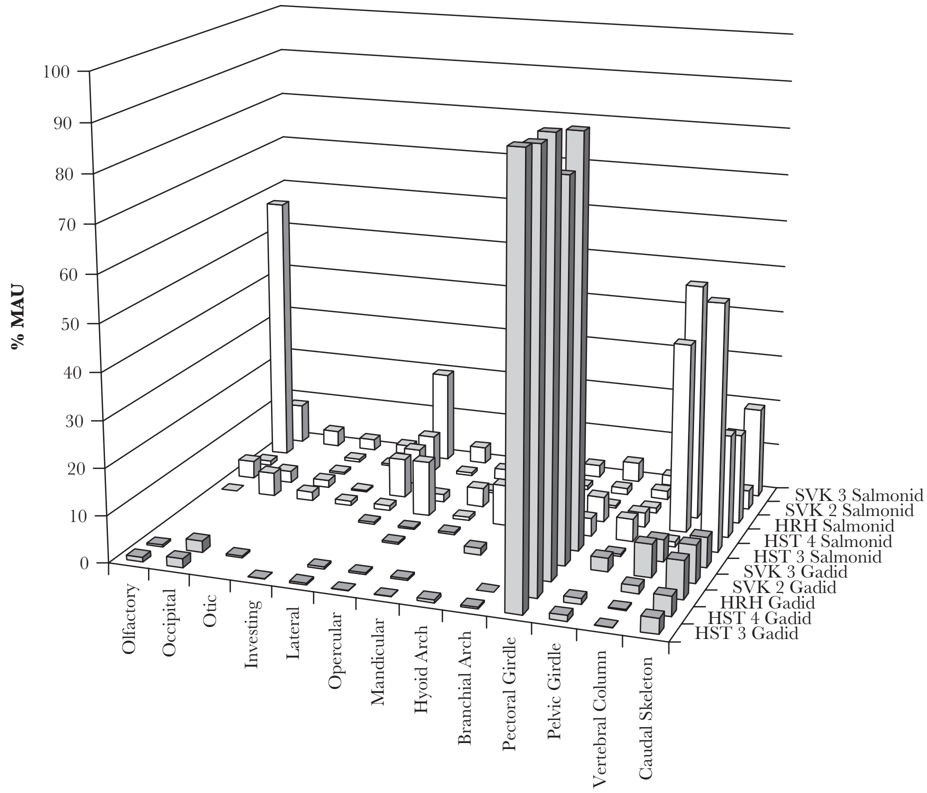
[33] See discussion in Amundsen *et al.* (2005).

Fig. 6. A comparison of the relative abundance of the three types of cod-family fish vertebrae. Thoracic and pre-caudal vertebrae are in the upper body, and caudal vertebrae are in the tail. The distribution in a complete cod fish is illustrated for reference.



It also seems clear that there was some variability in the type of dried fish reaching the different inland farms. While all phases at Hofstaðir, Hrísheimar, Steinbogi and Granastaðir are dominated by caudal vertebrae (typical of a consumption of *klipfisk*), both phases at Sveigakot include a higher relative percentage of thoracic and precaudal vertebrae. This suggests that two of the successive households at Sveigakot were being provisioned with at least some stockfish (which would carry a full set of precaudal and some thoracic vertebrae) as well as the klipfisk-like product being consumed on the other inland sites. On all the sites, haddock and cod (the two most common species consumed) seem to be treated identically—prepared mainly as *klipfisk* except at Sveigakot where both appear to have also sometimes been consumed as stockfish. Skeletal element analysis thus has potential not only for identifying producer and consumer site signatures, but also provides evidence for the type of product being distributed. From current evidence it seems that however they were processed, *not one* whole marine fish reaching the Mývatn consumers from the ninth century settlement down to the thirtheenth century—all marine fish arrived missing much of their

Fig. 7. Comparison of the major skeletal groups of the fish skeleton for both salmonid family (freshwater fish) and gadid family (marine fish) recovered from Hofstaðir, Sveigakot, and Hrísheimar midden deposits in the inland Mývatn district. While the salmonids are represented by most bones of the skeleton, the marine gadids lack most mouthparts and skull elements.



skeletons. It appears that freshly caught marine fish were not part of this pre-commercial distribution network, but that processed (probably dried) fish were regularly transported inland.

Local versus imported fish

The gadid family fish-bones range from 12 to 60 percent of all identified fish-bones in the five major collections, with the rest being the local freshwater trout and charr. Element frequency analysis again provides a strong contrast in the distribution of specimens that crosscuts period and site.

As Figure 7 indicates, the salmonids (local trout and charr) are represented by virtually all the bones of the complete skeleton, while the marine gadids are represented by partial skeletons in all five Mývatnssveit sites (dating from the late ninth to early thirtheenth century). Freshwater fish were being caught locally and processed on site, with butchery waste and food consumption waste winding up in the same midden deposits. This salmonid fish pattern in fact resembles the element distribution pattern of the domestic mammals (cattle, pig, sheep, and goats), which also reflect local slaughter, butchery and consumption patterns blending together in a common midden dump. While these large freshwater fish-bone collections have great potential for local environmental reconstruction,[34] their major significance for this paper is to demonstrate the contrast of skeletal element distribution between locally caught fish consumed fresh, and fish imported as partial skeletons.

Artisanal versus commercial species diversity

Figure 8 presents the mix of major species present in large archaeofauna from both northern Norway (Lofoten and Vesterålen) and Iceland. The two Iron Age sites of Bleik and Toften are dominated by fish, but show a high diversity in species landed and processed. The two phases of the nearby Storvågan site (a centre of the documented medieval commercial trade) shows a marked reduction in species diversity and a strong concentration on the Atlantic cod that provided the exportable product. In Iceland, the Viking age interior sites (Granastaðir as well as the Mývatnssveit sites) show a high diversity of species, with haddock bones outnumbering cod on some sites. The contrast with the twelfth-thirtheenth century and fifteenth century archaeofauna from the seasonal fishing station at Akurvík is striking, and again indicates a concentration of cod. We thus have reason to suspect that the Nordic consumers of the pre-twelfth century, pre-commercial marine fishery were tolerant of a wide range species circulating as preserved fish. Mono-specific targeting of Atlantic cod seems to be a phenomenon of the process of product standardization and commoditization.

[34] Lawson *et al.* (2005).

Fig. 8. Comparison of major identified fish taxa from sites in northern Norway and Iceland. Bleik and Toften in Norway date to the pre-Viking Iron Age, while the two phases from Storvågan date to the period of historically documented cod-dominated commercial fisheries. The ninth to thirteenth-century Icelandic sites show a comparably wide range of species brought inland, while the coastal fishing station at Akurvík is also dominated by cod in both major occupational phases. Reduced species diversity appears to be a critical archaeological indicator of high medieval commercial fishing.

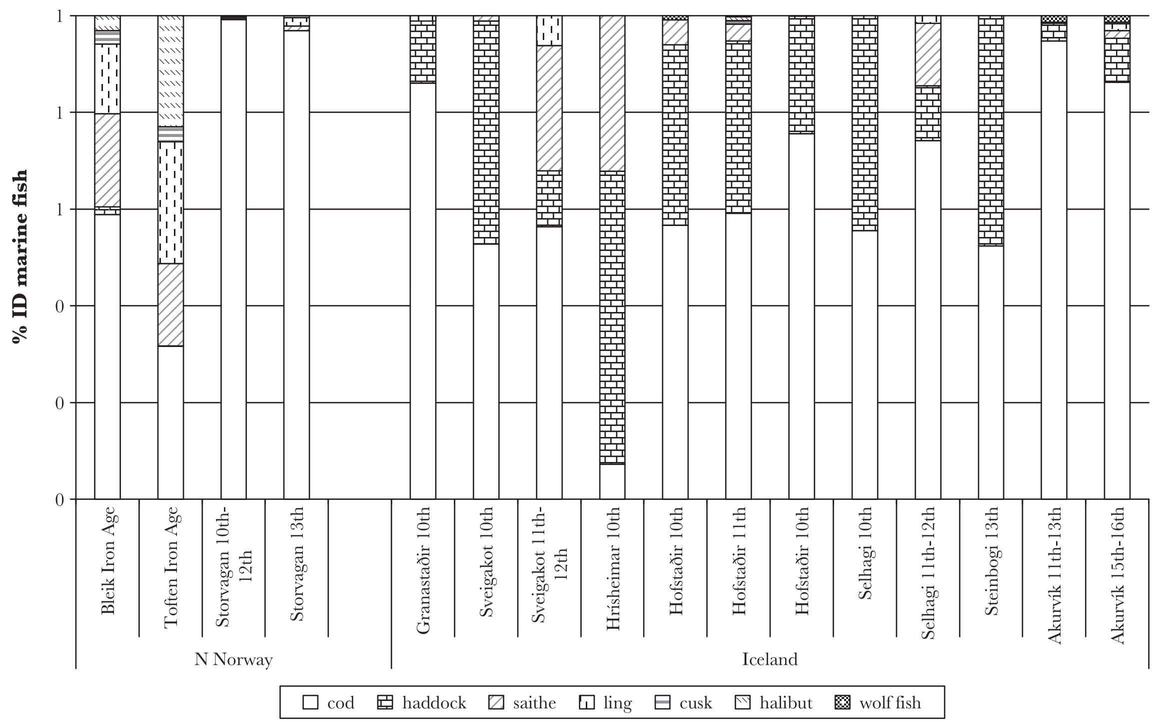
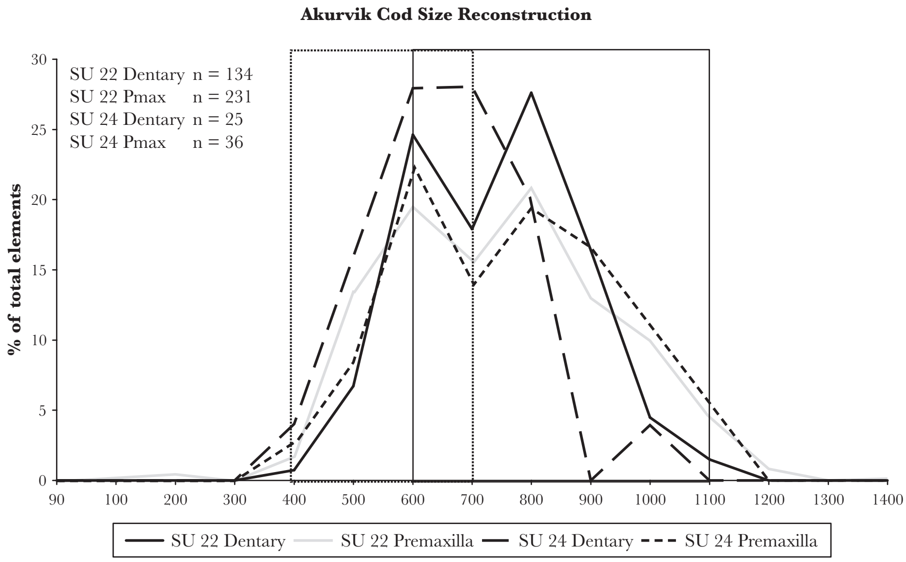


Fig. 9. A reconstruction of the live length (mm) using the dentary and premaxillary bones of cod fish from the coastal fishing station of Akurvík for its two major occupational periods (SU 24 = 11th–13th c, SU 22 = mid 15th c). The two bones provide closely similar distribution patterns, and the generally bimodal distribution peaks fall within the centers of the optimal stockfish size range (600–1100 mm) and the optimal *klipfisk* range (700–400 mm). Two different preserved fish products appear to have been produced at the same fishing station in both time periods.



Live length reconstruction

Fish size reconstruction is a critical element in a discussion of fisheries commercialization. Not all sizes of fish are suitable for curing. For the commercial stockfish, the modern industry has defined its standard to a fish 60–110 cm in live length. This allows for plenty of flesh after the drying is complete but the fish is not too oversized, so that spoiling does not occur prior to drying. *Klipfisk* traditionally uses smaller sized fish better able to dry split open, and under a wider range of temperatures.

The regression formulae of Wheeler and Jones provide widely used approaches to the reconstruction of live length from cod skeletal elements (particularly the dentary and premaxilla).[35] While these measur-

[35] Wheeler and Jones (1989).

able jaw elements are totally absent in our inland consumer sites, they are extremely abundant in the coastal sites of the West Fjords. Figure 9 presents the distribution of reconstructed cod length at Akurvík in the twelfth-thirtheenth century contexts (SU 24) and the mid fifteenth century contexts (SU 22). The solid box encloses the approximate 'stockfish window' while the dotted box encloses the range for optimal *klipfisk* production. It would appear that by the later Middle Ages, this seasonal fishing station was producing both products, perhaps for both a local intra-Icelandic market and for overseas export (as suggested by the element distribution analyses presented in figures 5 and 6).

Age reconstruction—and fish population change

As with size reconstruction, determining the age of fish from archaeological assemblages can provide a key baseline for analysis of both fishing patterns and the nature of the fish stocks being taken. Gadid fish-bones have proven to be a challenge in locating and counting incremental growth lines comparable to enamel/dentine annuli in mammal teeth. The modern fisheries industry uses the otolith (ear stone) for incremental analysis of growth and seasonality but otoliths are nearly pure calcium carbonate, and disappear completely under depositional environments that preserve virtually all other skeletal elements in excellent condition. Where otoliths survive, they are usually in statistically insignificant numbers.

Research and testing at the Brooklyn Zooarchaeology Laboratory indicates that the clearest and easiest way to collect reliable age data for individual codfish is by counting the incremental growth rings on the face of the centrum of the atlas vertebra- an element which preserves well and is regularly deposited at producer sites. Coupled by a regression formula developed by Inge Enghoff, both size and age data can be collected for the same archaeological individual.[36] At Akurvík, current work indicates that for codfish within the 60–110 cm 'stockfish window' the age range falls between 6 and 12.5 years of age. Today these would be fairly old cod for this size, at least by modern industry standards.

Based on data published in *Annales Biologiques* the modern age range of *Gadus morhua* landed in the North Atlantic in this size range is between two and ten years of age.[37] In the current sample, 73.2 percent

[36] Inge Enghoff (1994).
[37] Parrish (1982; 1983; 1984).

of the modern fish fall between four and five years, while in the archaeological material, 65 percent of the fish fall between eight and ten years for the stockfish range. While the size comparisons do not point to a great difference in fish length, the mode of the age of the cod population was practically cut in half from the Akurvik times to the modern era as the most represented age class dropped from nine to ten years to five years.

It would appear that the rate of growth of twentieth century cod has been significantly more rapid than in medieval times, probably due to depletion of larger and older individuals by fishing. This age/size difference is quite significant to the spawning cod population, since a 10 year-old fish may lay many millions more eggs than a 4–5 year-old of the same body size.[38] The relevance of zooarchaeological 'paleofisheries' data to current efforts to sustainably manage cod stocks and other marine resources can only increase, as ancient bimolecular evidence and isotopic analyses are added to a growing suite of technical advances applied to a growing body of excavated evidence across the North Atlantic.

Human and animal isotopes and dietary reconstruction

Radiocarbon dates are affected by the amount of (older) marine carbon ingested in life, and thus the detection of a marine carbon reservoir effect is of considerable importance for chronology as well as dietary reconstruction.[39] Stable carbon and nitrogen isotope ratios in human and animal bone are increasingly being used to reconstruct past diets. In the North Atlantic, the carbon isotope ratio in human or animal bone has been used to assess the degree of participation in the marine food web.[40] A recent series of radiocarbon dates and carbon and nitrogen assays have been carried out by Dr. Gordon Cook of the Scottish Universities Reactors Centre on a steadily expanding number of pre-Christian burials from many districts of Iceland. Since many of these pagan graves contained the bones of horses (and sometimes dogs) as well as humans, it is possible to provide a comparison between herbivores eating terrestrial plants and omnivores potentially consuming both marine and terrestrial food.

---

[38] See Perdikaris (1998) for more extensive discussion.
[39] Ascough *et al.* (2004).
[40] See discussion in Arneborg *et al.* (1999); Barrett *et al.* (2001).

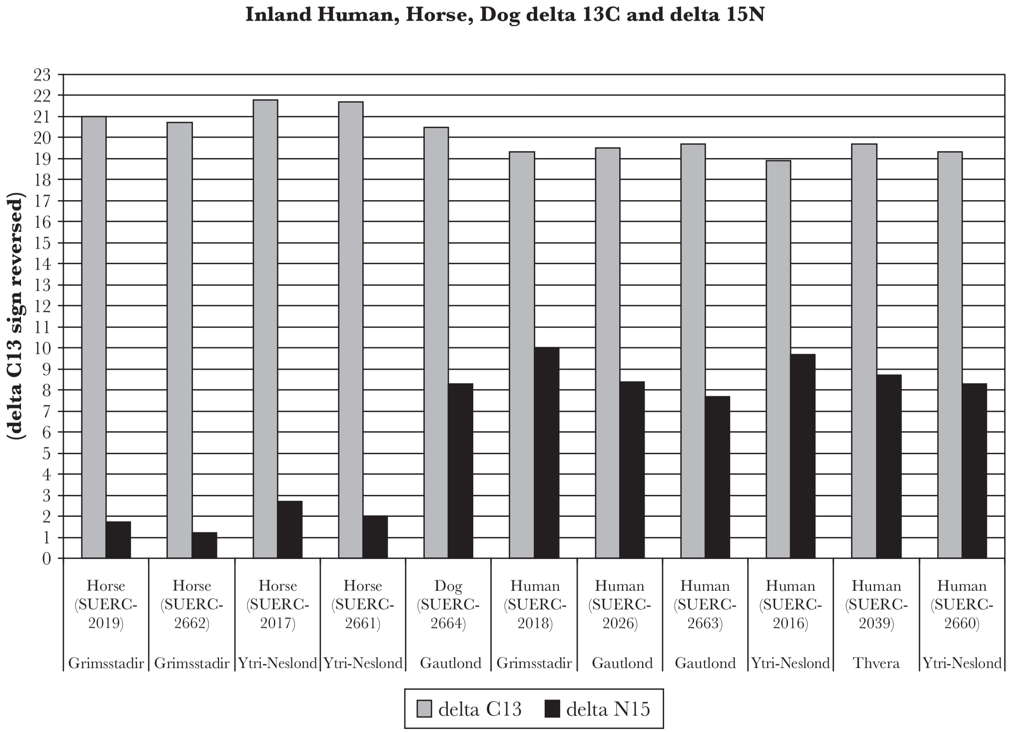
Figure 10 graphs the carbon and nitrogen isotopic data from horse, human, and dog bones from pagan graves in the inland Mývatn district (close to the farm sites whose archaeofauna are discussed here). Arneborg and her colleagues suggest for population groups from high northern latitudes that a δ13C end member of around –21.0‰ would be appropriate for 100 percent terrestrial diets while –12.5‰ would represent the end member for 100 percent marine diets.[41] By this standard, the horses all show completely terrestrial carbon signatures, while the dogs and the humans appear to show some admixture of marine carbon. However, the probable consumption of substantial amounts of freshwater fish suggested by the zooarchaeological collections may present complications. Detailed information on the effect of freshwater fish consumption on human bone collagen δ13C values is not well documented, but Cook and his colleagues have demonstrated a similar range of δ13C values (–18.2 to –19.5‰) for consumption of significant freshwater resources at *Schela Cladovei* in the Iron Gates Gorge of the River Danube during the Mesolithic era.[42] However, these small shifts in δ13C were accompanied by significantly greater shifts in δ15N (range = +13.2 to +15.3‰ cf. approximately +8‰ for a totally terrestrial diet). The Mývatnssveit human and dog δ15N values were lower in range (+7.7 to +10.0‰), suggesting that a freshwater fish effect is not the whole explanation for the contrasting carbon ratios between horses, humans, and dogs. Additional analyses directly comparing isotopic ratios in marine and freshwater fish bones and terrestrial mammal bones from the Mývatn sites are now underway, and a fuller understanding of the isotopic patterning of these early inland burials should soon be possible.

Between subsistence and globalization: outlines of Nordic maritime economy prior to AD 1000

Thanks to sustained scholarly co-operative efforts, we are beginning to see an outline of the undocumented pre-fish event horizon, pre-Hanseatic Nordic maritime economy. We now recognize that the source of the fish preservation skills that revolutionized northwestern

[41] Arneborg *et al.* (1999).
[42] Cook *et al.* (2002).

Fig. 10. The stable carbon and nitrogen isotope levels for horse, dog and human bones from inland Mývatn sites. The radiocarbon dates based on the horse bones indicate late ninth to early tenth-century burial. The contrast between entirely terrestrial horse carbon ratios and the slightly marine human and dog ratios suggest some consumption of seafood even by these Viking age inland lake dwellers. Note the sign of the delta C13 assays has been reversed to allow for more readable graphing against the N15 figures.



European fisheries in the eleventh-twelfth century must be sought in the Scandinavian world of the early Viking age. When the highlands of Iceland were settled soon after 871, Nordic farmers of all classes thought it vital and found it practical to provision their households with dried fish from the distant sea. These Scandinavian settlers of inland Iceland were quite able to secure a steady supply of preserved fish before, during, and after the British fish event horizon.

We do not yet fully understand the role of dried fish in the early Icelandic seasonal round, but a source of high quality protein that could be relied upon in late winter would certainly be attractive. Clearly, dried marine fish was seen as important enough to secure in quantities large enough to regularly appear in refuse deposits and to affect the isotopic make up of inland-buried human and dog bones. We also do not yet understand the social mechanisms that regularly transported dried fish products (apparently mainly klipfisk but with some stockfish mixed in) so far inland. Webs of gift-exchange, labour exchange, chieftain accumulation and redistribution, annual journeys from inland to coast, or purchase at regional market fairs are all plausible means of moving coastal products inland, and the ethnographic record of early modern Iceland suggests multiple pathways might have co-existed at the same time.

We also do not yet know if the different elements of the marine products transferred inland were socially and seasonally integrated, or if dried fish were marketed separately from sea mammal meat, sea-bird carcasses or sea-bird eggs. There is some suggestion of fairly swift and direct connections between inland farms and the coast to move perishables like porpoise meat, seaweed, or marine bird eggs. This might argue for direct travel by inland people to the coast in spring or early summer (when eggs could be collected and migratory sea-birds would be present). However, the production of stockfish is a winter activity, and both stockfish and *klipfisk* take months to prepare, making both products unlikely to be created by inland householders making a short trip to the coast. This may explain the total absence of whole, recently caught marine fish from the inland sites in Iceland.

Both stockfish and *klipfisk* are light and easy to move in bulk, and in historic times were regularly transported inland on packhorses. The early date for the deposition of the first processed fish (directly upon the Landnám tephra layer at Sveigakot) underlines that the coastal connection was established very early in the settlement process. It did

not emerge as a result of increasing population and developing market exchange late in the settlement age but was part of the very early Viking age subsistence package. We must model some sort of distribution system in the context of the first stages of chieftain-dominated settlement which cross-cut what were to become different localities and communities (*hreppar*), as Mývatn is separated from the sea by two later hreppar boundaries. In north Norway, elites were closely involved in the movement of bulk stockfish by ship, and Edvardsson has argued for substantial inter-regional movement of fish from the West Fjords into other parts of Iceland in the Viking age.[43]

While more research is needed, it appears certain that there was some sort of organized fishery and preserved fish distribution system in place in ninth-tenth century Iceland that successfully moved substantial amounts of fish and other marine products inland. This system must have been imported from mainland Scandinavia rather than the northern British Isles, and almost certainly draws upon prehistoric roots in north Norway. In scale, it appears to have been a system somewhere between a household-level effort and the proto-world system network of the Hanseatic traders. Tolerant of high species diversity, variable in fish cutting standards, and certainly smaller in scale, this pre-commercial, un-monetized Scandinavian Viking age seafood distribution system never the less appears to be the direct ancestor of the modern commercial fisheries in Northwest Europe.

For some time this early Nordic seafood production and distribution system seems to have remained just a northern ethnic specialty rather than an economic revolution. As Barrett and his colleagues have argued, this early Viking age Nordic seafood processing and distribution system did not immediately trigger the expanded trade to non-Scandinavian Britain immediately following the initial Norse settlement of the Northern and Western isles in the ninth century.[44] In Britain, a gap of 100–150 years separates the initial Viking age settlements in the north (with their isotopic evidence for increased human seafood consumption and increase in frequency of large gadid bones) from the archaeologically visible fish event horizon of c. 950–1050 in inland sites to the south. The fish event horizon thus coincides instead with the 'second Viking age' Sawyer characterized both by intensified warfare and

[43] Edvardsson (2005).
[44] Barrett *et al.* (2004; this volume).

increasing interaction of Scandinavians and Anglo-Saxons at all social levels in England.[45] During this period, the potential of dried fish as a commodity and its potential for feeding armies, provisioning towns, and raising money may have been widely demonstrated. As Scandinavian elites became increasingly Christian, managers of towns and manors rather than heathen raiders, varied aspects of Nordic culture from language to art became integrated with the larger societies of Christian Europe. The short-lived Anglo-Scandinavian dynasty briefly uniting English and Scandinavian thrones, founded 1014 by Sven Forkbeard and expanded by his more famous son Knut 'the great' (died 1039), may be one candidate for the mechanism for the Nordic contribution to the fish event horizon, but other possibilities need investigation as well. However the technology transfer may have taken place, the long-term consequences of the pre-commercial Norse fish distribution network 'going global' were profound. The commonplace expertise of Nordic fisher-folk and Nordic chieftains in making and marketing dried fish, though an unworthy subject for sagas, may well be one of the most lasting legacies of the Viking age.

Bibliography

Amorosi, T. (1996) *Icelandic zooarchaeology: New data applied to issues of historical ecology, paleoeconomy and global change* (Unpublished PhD thesis, City University of New York, New York: 1996).

Amorosi, T., J.W. Woollett, S. Perdikaris, and T.H. McGovern (1996) 'Regional zooarchaeology and global change research: Problems and potentials', *World Archaeology*, 28 no. 1 (1996) 126–157.

Amundsen, C.P. (2003) 'Early medieval fishing activity in the Kola peninsula' in A.F. Guzman, O.J. Polaco and F.J. Aguilar eds., *Presence of the archaeoichthyology in Mexico*. Proceedings of the 12th meeting of the Fish Remains Working Group of the International Council for Archaeozoology. 4–12 September 2003 (Guadalajara, Jalisco, Mexico: 2003) 11–18.

——. (2004) 'Farming and maritime resources at Midbaer on Flatey in Breiðafjord, North-West Iceland' in R.A. Housely and G. Coles eds., *Atlantic connections and adaptations; economies, environments and subsistence in lands bordering the North Atlantic,* AEA/NABO Environmental Archaeology Monographs 21 (London: 2004) 23–64.

Amundsen, C.P., J. Henriksen, E. Myrvoll, B. Olsen and P. Urbanczyk (2003) 'Crossing borders: multi-room houses and inter-ethnic contacts in Europe's extreme North', *Fennoscandia Archaeologica* XX (2003) 79–100.

[45] Sawyer (1997).

Amundsen, C.P., S. Perdikaris, T.H. McGovern, Y. Krivogorskaya, M. Brown, K. Smiarowski, S. Storm, S. Modugno, M. Frik, M. Koczela (2005) 'Fishing booths and fishing strategies in medieval Iceland: an Archaeofauna from the of Akurvík, North-West Iceland', *Environmental Archaeology* 10 no. 2 (in press).
Arneborg, J., J. Heinemeier, N. Lynnerup, H.L. Nielsen, N. Rud, and Á.E. Sveinbjörnsdóttir (1999) 'Change of diet of the Greenland Vikings determined from stable carbon isotope analysis and ^{14}C dating of their bones', *Radiocarbon* 41 (1999) 157–168.
Ascough, P., G. Cook, A. Dugmore, J. Barber, E. Hingney, M. Scott. (2004) 'Holocene variations in the Marine Radiocarbon Reservoir Effect', *Radiocarbon* 46 no. 2 (2004) 611–620.
Barrett, J. (1995). *Few know Earl fishing-clothes' Fish middens and the economy of the Viking age and late Norse Earldoms of Orkney and Caithness, Northern Scotland* (Unpublished PhD thesis, University of Glasgow, Glasgow: 1995).
Barrett, J., R.A. Nicholson and R. Cérron-Carrasco (1997) 'Fish trade in Norse Orkney and Caithness: a zooarchaeological approach', *Antiquity* 71 (1997) 616–638.
Barrett, J. (1999), 'Archaeoicthylogical evidence for long term socioeconomic trends in northern Scotland 3500 BC–AD 1500', *Journal of Archaeological Science* 26 (1999) 353–388.
Barrett, J., R.P. Beukens, I.A. Simpson, P. Ashmore, S. Poaps, J. Huntley (2000) 'What was the Viking age and when did it happen? A view from Orkney', *Norwegian Archaeological Review* 33 (2000) 1–39.
Barrett, J., R.P. Beukens, R.A. Nicholson (2001) 'Diet and ethnicity during the Viking colonization of Northern Scotland: evidence from fish bones and stable carbon isotopes', *Antiquity* 75 (2001) 145–154.
Barrett, J.H., A.M. Locker and C.M. Roberts (2004) 'The origin of intensive marine fishing in medieval Europe: The English evidence', *Proceedings of the Royal Society* B 271 (2004) 2417–2421.
Barrett, J., *et al.* (2004) 'Dark Age Economics' revisited: The English fish bone evidence AD 600–1600', *Antiquity* 78 no. 301 (2004) 618–636.
Bertelsen, R. (1991) 'A north-east Atlantic perspective' in G.F. Bigelow ed., *The Norse of the North Atlantic*. Acta Archaeologica vol. 61 (Copenhagen: 1991) 22–28.
Bigelow, G.F. (1984) *Subsistence in late Norse Shetland: an investigation into a northern island economy of the Middle Ages* (Unpublished PhD thesis, University of Cambridge: 1984).
——. (1985) 'Sandwick Unst and the late Norse Shetlandic economy' in B. Smith ed., *Shetland Archaeology, New Work in the 1970's* (Lerwick: 1985) 95–127.
Cannon, D. Y. (1987) *Marine fish osteology: a manual for archaeologists*. Department of Archaeology, Simon Fraser University, Publication no. 18 (1987) 1–133.
Cérron-Carrasco R. (1994) 'The investigation of fish remains from an Orkney farm mound' in W. van Neer. ed., *Fish exploitation in the past. Proceedings of the 7th meeting of the ICAZ Fish Remains Working Group* (Brussels: 1999) 209.
Church, M., S. Arge, S. Brewington, T.H. McGovern, J. Woollett, S. Perdikaris, I.T. Lawson, G.C. Cook, C. Amundsen, R. Harrison, Y. Krivogorskaya (2005) 'Puffins, pigs, cod and barley: paleoeconomy at Undir Junkarinsfløtti, Sandoy, Faroe Islands', *Environmental Archaeology* 11 (in press).
Cook, G.T., C. Bonsall, R.E.M. Hedges, K. McSweeney, V. Boroneanţ, and P.B. Pettitt, (2001) 'A freshwater diet-derived reservoir effect at the stone age sites in the Iron Gates gorge', *Radiocarbon* 43 (2001) 453–460.
——. (2002) 'Problems of dating human bones from the Iron Gates', *Antiquity* 76 (2002) 77–85.
Dennis, A., P. Foote, and R. Perkins (1993) *Laws of early Iceland, Grágás: The Codex Regius of Grágás with material from other manuscripts* 2 vols. (Winnipeg: 1993).
Dockrill, S.J., J.M. Bond, V.E. Turner (2001) 'Old Scatness/Jarlshof Environs Project: Field season 2000', *Interim Report* no. 6. Bradford Archaeological Sciences Research 10 (University of Bradford/Shetland Amenity Trust: 2001).

Edvardsson, R. (1996) *Fornleifaskráning í Bolungarvík, fyrsti hluti, Kaupstaðurinn og jarðirnar næstar honum* (Fornleifastofnun Íslands: 1996).

——. (2002) 'Statistical analysis of the 1703–1712 land register: Four districts in the northwest of Iceland' in G. Guðmundsson ed., *Current Issues in Nordic Archaeology, Proceedings of the 21st conference of Nordic Archaeologists* (Reykjavik: 2002) 189–197.

Edvardsson, R., S. Perdikaris, T.H. McGovern, N. Zagor, M. Waxman (2004). 'Coping with hard times in North-West Iceland: Zooarchaeology, history, and landscape archaeology at Finnbogastaðir in the 18th century', *Archaeologica Islandica* 3, 20–48.

Edvardsson, R. (2005) 'New perspectives on the archaeology of the Westfjords', *Archaeologica Islandica* 4 (in press).

Edvardsson, R. and T.H. McGovern (2005) 'Archaeological excavations at Vatnsfjörður 2003–04', *Archaeologica Islandica* 4 (in press).

Edwards, K.J., P.C. Buckland, A.J. Dugmore, T.H. McGovern, I.A. Simpson and G. Sveinbjarnardóttir (2004) 'Landscapes *circum*-Landnám: Viking settlement in the North Atlantic and its human and ecological consequences: a major new research programme', in R. Housley and G.M. Coles, eds. *Atlantic connections and adaptations: economies, environments and subsistence in lands bordering the North Atlantic* (Oxford: 2004) 260–271.

Enghoff, I. B. (2003) *Hunting, fishing, and animal husbandry at the Farm Beneath the Sand, Western Greenland: an archaeozoological analysis of a Norse farm in the Western Settlement*. Meddelelser om Grønland Man and Society 28 (Copenhagen: 2003).

Friðriksson, A. and O. Vésteinsson (2003) 'Creating a past. A historiography of the settlement of Iceland' in J. Barrett ed., *Contact, continuity and collapse: The Norse colonization of the North Atlantic*. Studies in the early Middle Ages 5 (Turnhout: 2003) 139–161.

Gade, J.A. (1951) *The Hanseatic control of Norwegian commerce during the late Middle Ages* (Leiden: 1951).

Grayson, D. (1984) *Quantitative zooarchaeology* (New York: 1984).

Grönvold, K., N. Óskarsson, S.J. Johnsen, H. Clausen, C.U. Hammer, G. Bond and E. Bard (1995) 'Ash layers from Iceland in the Greenland GRIP ice core correlated with oceanic and ash sediments', *Earth and Planetary Science Letters* 135 (1995) 149–155.

Jones, A.K.G. (1991) *The fish remains from Freswick Links, Caithness* (Unpublished PhD thesis, University of York: 1991).

Krivogorskaya, Y., S. Perdikaris, T.H. McGovern (2005a) 'Fish bones and fishermen: the potential of zooarchaeology in the Westfjords', *Archaeologica Islandica* 5 (in press).

——. (2005b) 'Cleaning up the farm: A later medieval archaeofauna from Gjögur, a Fishing Farm of NW Iceland' in B. Grønnow, J. Arneborg and H.C. Gulløv eds., *Dynamics of Northern Societies* (Copenhagen: in press).

Lawson, I.T., F.J. Gathorne-Hardy, M.J. Church, A. Einarsson, K.J. Edwards, P. Mayewski, T.H. McGovern, C. Amundsen and G. Sveinbjarnardóttir (2005) 'Human impact on freshwater environments in Norse and early medieval Iceland' in B. Grønnow, J. Arneborg, H.C. Gulløv eds., *The Dynamics of northern societies* (Copenhagen: in press).

McGovern, T.H. (1982) *Animal bones from Aðalból in Hrafnkelsdalur, East Iceland* (Unpublished report on file National Museum of Iceland, Reykjavik: 1982).

——. (1985) 'Contributions to the paleoeconomy of Norse Greenland', *Acta Archaeologica* vol 54 (1985) 73–122.

——. (2004) 'North Atlantic Biocultural Organization (NABO) 10 years on: Science, education, and community' in R. Housley and G.M. Coles eds., *Atlantic connections and adaptations: economies, environments and subsistence in lands bordering the North Atlantic* (Oxford: 2004) 254–259.

McGovern, T.H., S. Perdikaris, C. Tinsley (2001) 'Economy of Landnám: the evidence of zooarchaeology' in A. Wawn and T. Sigurdardottir eds., *Approaches to Vinland*. Sigurdur Nordal Institute. Studies 4 (Reykjavik: 2001) 154–165.
McGovern, T.H., O. Vésteinsson, A. Fridriksson, M. Church , I. Lawson, I.A. Simpson, A. Einarsson, A. Dugmore, G. Cook, S. Perdikaris, K. Edwards, A.M. Thomson, W.P. Adderley, A. Newton, G. Lucas, O. Aldred (2005) 'Landscapes of settlement in northern Iceland: Historical ecology of human impact and climate fluctuation on the millennial scale', *American Anthropologist* (in press).
Nielssen, A.R. (1994) 'The importance of the Hanseatic trade for the Norwegian settlement in Finnmark', V. Henn and A. Nedkvitne eds., *Norwegen und die Hanse* (Frankfurt am Main: 1994).
Nielssen, A.R. and P. Christensen (1996) 'Norwegian fisheries 1100–1970' in *The North Atlantic fisheries 1100–1970*. Studia Atlantica no. 1 (Esbjerg: 1996).
Nicholson, R. (1998) 'Fishing in the northern isles, a case study based on fish bone assemblages from two multi-period sites on Sanday, Orkney', *Environmental Archaeology* 2 (1998) 15–29.
Ogilvie, A.E.J. (1997) 'Fisheries, climate and sea ice in Iceland: an historical perspective' in D. Vickers ed., *Marine resources and human societies in the North Atlantic since 1500* (St. Johns: 1997) 69–87.
Perdikaris, S. (1996) 'Scaly heads and tales: Detecting commercialization in early fisheries' in A. Morales ed., *Ichthyoarchaeology and the Archaeological record 8th ICAZ Conference Proceedings. Archaeofauna* 5 (1996) 21–33.
——. (1998) 'The transition to a commercial economy: Lofoten fishing in the Middle Ages. A preliminary report', *7th ICAZ Conference Proceedings, September 1994, Konstanz, Germany. Anthropozoologica* 25–26 (1997) 505–510.
——. (1999) 'From chiefly provisioning to commercial fishery: Long term economic change in Arctic Norway', *World Archaeology* 30 no. 3 (1999) 388–402.
Perdikaris, S. and T.H. McGovern (2005) 'Walrus, cod fish and chieftains: patterns of intensification in the Western North Atlantic' in T. Thurston ed., *New Perspectives on Intensification* (New York: in press).
Perdikaris, S., P. Lahtiperä, Y. Krivogorskaya, T.H. McGovern (2004). *FISH-BONE 1.1 CD identification manual for Gadid fish in the North Atlantic.* NABO cooperative and the ICAZ Fish Remains Working Group available via nabo@voicenet.com.
Rackham, D.J., E. Allison, S. Colley, B. Lambden, S. Nye and M. Owen (1996) 'Beachview, Birsay, the biological assemblage' in C.D. Morris ed., *The Birsay Bay Project 2. Sites in Birsay Village and on the Brough of Birsay* (Durham: 1996) 161–191.
Sawyer, P. ed. (1997) *Oxford illustrated history of the Vikings* (Oxford: 1997).
Simpson, I.A., S. Perdikaris, G. Cook, J.L. Campbell, W.J. Teesdale (2000) 'Cultural sediment analyses and transitions in early fishing activity at Langenesvaeret, Vesterålen, northern Norway', *Geoarchaeology* 15 (2000) 743–763.
Sveinbjornsdottir, A.E., J. Heinemeier and G. Gudmundsson (2004) 'C14 dating of the settlement of Iceland', *Radiocarbon* 46 no. 1 (2004) 387–394.
Vésteinsson, O. (1998) 'Patterns of settlement in Iceland. A study in Pre-History', *Saga-Book of the Viking Society* XXV (1998) 1–29.
——. (2000) 'The archaeology of landnám. Early settlement in Iceland' in W.W. Fitzhugh and E. Ward eds., *Vikings. The North Atlantic saga* (Washington: 2000) 164–174.
——. (2004) 'Icelandic farmhouse excavations: Field methods and site choices', *Archaeologia Islandica* 3 (2004) 71–100.
Vésteinsson, O., T.H. McGovern and C. Keller (2002) 'Enduring Impacts: social and environmental aspects of Viking age settlement in Iceland and Greenland', *Archaeologica Islandica* 2 (2002) 98–136.
Wheeler, A. and A. Jones (1989) *Fishes* (Cambridge: 1989).