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The origins of intensive marine fishing in medieval Europe: the English evidence

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The catastrophic impact of fishing pressure on species such as cod and herring is well documented. However, the antiquity of their intensive exploitation has not been established. Systematic catch statistics are only available for *ca.*100 years, but large-scale fishing industries existed in medieval Europe and the expansion of cod fishing from the fourteenth century (first in Iceland, then in Newfoundland) played an important role in the European colonization of the Northwest Atlantic. History has demonstrated the scale of these late medieval and post-medieval fisheries, but only archaeology can illuminate earlier practices. Zooarchaeological evidence shows that the clearest changes in marine fishing in England between AD 600 and 1600 occurred rapidly around AD 1000 and involved large increases in catches of herring and cod. Surprisingly, this revolution predated the documented post-medieval expansion of England's sea fisheries and coincided with the Medieval Warm Period—when natural herring and cod productivity was probably low in the North Sea. This counterintuitive discovery can be explained by the concurrent rise of urbanism and human impacts on freshwater ecosystems. The search for 'pristine' baselines regarding marine ecosystems will thus need to employ medieval palaeoecological proxies in addition to recent fisheries data and early modern historical records.

Keywords: marine ecosystems baselines; cod; herring; archaeology; Middle Ages; climate change

1. INTRODUCTION

It is now uncontroversial that overfishing has led to catastrophic depletion of marine fish stocks (Christensen *et al.* 2003; Hutchinson *et al.* 2003). It is also clear, however, that the scale of the problem remains unknown. An understanding of overfishing requires comparison of current observations with baseline records of marine ecosystems in their 'pristine' state (Jackson *et al.* 2001; Holm 2003). But how long have humans influenced populations of commercial species such as cod and herring? Although fisheries statistics have been collected for only the past 100 years at most, recent studies suggest that measurable impacts on marine ecosystems in the North Sea and North Atlantic may have begun centuries ago. Using archaeological fish remains, researchers have attempted to demonstrate a reduction in the size of fish caught through time (Amorosi *et al.* 1994; Jackson *et al.* 2001) and changes in fish growth rates that may be correlated with fishing intensity (Van Neer *et al.* 2002). Unfortunately, however, in studies of fish growth rates it is not possible to control for confounding environmental variables such as long-term climate shifts. Moreover, human choice and differences in fishing technology through time bias interpretations of fish size distributions (Leach & Davidson 2000). It is thus difficult to directly measure the impact of fishing on ancient marine ecosystems.

It is possible, however, to demonstrate when Europeans began to intensify their fishing effort—to *catch* herring, cod and related species on a significant scale. We determine the origin of intensive, probably commercial, cod and herring fishing by assessing the relative abundance (by number of identified specimens) of these taxa in 127 English archaeological fish bone assemblages that date from the seventh to the sixteenth centuries AD. We show that the most dramatic change in marine fishing throughout this millennium occurred, not with the post-medieval expansion of England's fisheries to Iceland and Newfoundland as one might expect (Starkey *et al.* 2000), but within a few decades of AD 1000. Moreover, this 'fish event horizon' coincided with the Medieval Warm Period when cod and herring productivity was probably low in the North Sea. By determining this temporal framework, it is possible to suggest the appropriate chronology for future palaeoecological baseline research.

2. METHODS

A summary of the 127 assemblages surveyed in this study, including references, is provided in electronic Appendix A. The sample size threshold was set at 50 or more identified bone specimens owing to the small number of fish bones recovered at most pre-eleventh century (particularly rural) settlements. Assemblages derived from fish gut contents (gutting stations) or shipwrecks have been excluded to minimize irrelevant outliers, as have collections that could not be broadly attributed to one of five two-century periods. Assemblages that overlapped the critical tenth to eleventh century transition period have also been excluded unless otherwise noted. The designation urban is used in a broad sense to include the 'proto-urban' wics of Anglo-Saxon England (Hill 2001). Inland sites are classified as those more than 10 km from the coast and not on an estuary. London, for example, is thus estuarine rather than inland.

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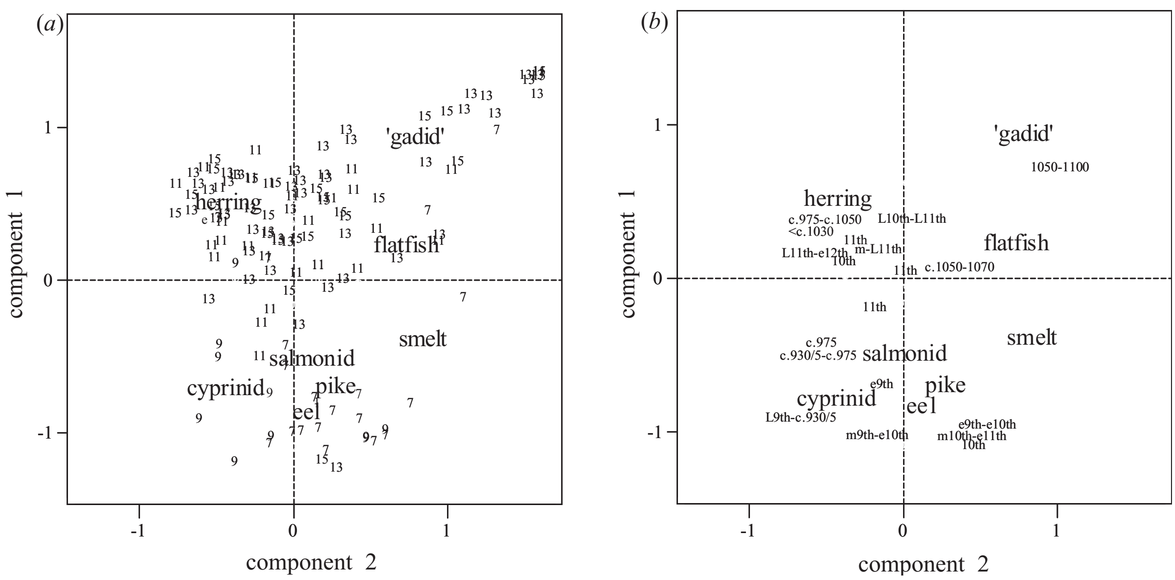

Figure 1. (*a*) Axes 1 and 2 of a correspondence analysis based on the abundance (by number of identified specimens) of the eight most common fish taxa in 127 English archaeological assemblages. Each assemblage is coded by the two-century period to which it best belongs: seventh to eighth (7), ninth to tenth (9), eleventh to twelfth (11), thirteenth to fourteenth (13) and fifteenth to sixteenth (15). The taxa with the highest contributions (out of a total of 1) to component 1 are eel (0.44), 'gadids' (0.23), herring (0.16) and cyprinids (0.12). 'Gadids' (0.36), herring (0.35) and flatfish (0.16) contribute most to component 2. With the exception of a few unusual cases discussed in the text, assemblages that predate the eleventh to twelfth centuries are associated with eel and cyprinids—migratory and freshwater taxa—rather than herring and gadids. (*b*) The correspondence analysis in (*a*) redisplayed to show only those assemblages from around the end of the first millennium AD that can be dated to within *ca*. 100 years. One assemblage predating c. AD 1030, but without a clear start date, is also included. The abbreviations indicate early (e), middle (m) and late (L) within a century. These results indicate that the marked increase in herring and 'gadid' fishing occurred within a few decades of AD 1000.

For each assemblage, the abundance of eight taxonomic groups was recorded by number of identified specimens. These taxa dominate the English fish bone record throughout the millennium in question. The marine taxa are herring and cod-like fishes ('gadids'—for present purposes this group is treated as including the related hake and excluding the freshwater burbot). The freshwater taxa are fishes of the carp family (cyprinids) and pike. Taxa that migrate between sea and rivers are European eel, salmon and trout (salmonids), smelt and flatfish (a group that includes flounder, which enters fresh water, but also marine species). Where data were not published, archive reports were consulted with the permission of the relevant analysts. Correspondence analysis, boxplots and Mann–Whitney tests (Baxter 2003) were then employed to discern chronological patterning in the relative abundance of marine vis-à-vis freshwater and migratory taxa, and thus the growth of sea fishing.

Differences in site location by period do not bias the results. Only six coastal assemblages are recorded, and these are spread from the seventh and eighth to the fifteenth and sixteenth centuries. There is an uneven distribution of estuarine (59 in total) and inland (62 in total) site locations by period ($\chi^2 = 15.42$, d.f. $= 4$, $p = 0.004$). However, it is inland sites that are underrepresented prior to the eleventh century, not vice versa. Thus, this pattern strengthens the observation that non-marine species were preferred prior to the end of the first millennium AD.

The degree to which recovery of the fish bone entailed sieving (partial or total) varied from assemblage to assemblage, but does not show chronological patterning ($\chi^2 = 5.62$, d.f. $= 4$, $p = 0.230$) and is thus unlikely to bias the overall results (Jones 1982). Where known, the minimum mesh size used does vary by period (Kruskal–Wallis $\chi^2 = 19.42$, d.f. $= 4$, $p < 0.001$), but the use of finer sieves is associated with eleventh century and later assemblages. Thus it is unlikely to be responsible for the patterns identified, in which large cod and related species became more common at the expense of smaller taxa such as eel and cyprinids. It could, however, have a minor impact on the relative abundance of herring.

3. RESULTS

When the eight taxonomic groups considered are compared using correspondence analysis (figure 1*a*), it is clear that virtually all catches from the seventh to the tenth centuries were dominated by freshwater and migratory species (particularly cyprinids and eels). By contrast, most eleventh century and later catches had far more herring and/or 'gadids'. Flatfish are predictably intermediate between these groups, given their mix of freshwater and marine species. In the thirteenth to sixteenth centuries, some assemblages were dominated by 'gadids' alone. There is no distinctive pattern associated with the fifteenth to sixteenth centuries, when the English cod fishery expanded first to Iceland and later to Newfoundland (Starkey *et al.* 2000). This implies that changes in fishing in the eleventh to twelfth centuries were more dramatic than during better-documented later developments.

The small number of outliers can be easily explained. One thirteenth/fourteenth-century case and one fifteenth/sixteenth-century assemblage resemble pre-eleventh-century examples because they consist almost entirely of eel (assemblages 73 and 116; see electronic Appendix A). They probably represent specialized stores. The few early assemblages associated with high proportions of 'gadids' and/or herring are all coastal (less than 10 km from the

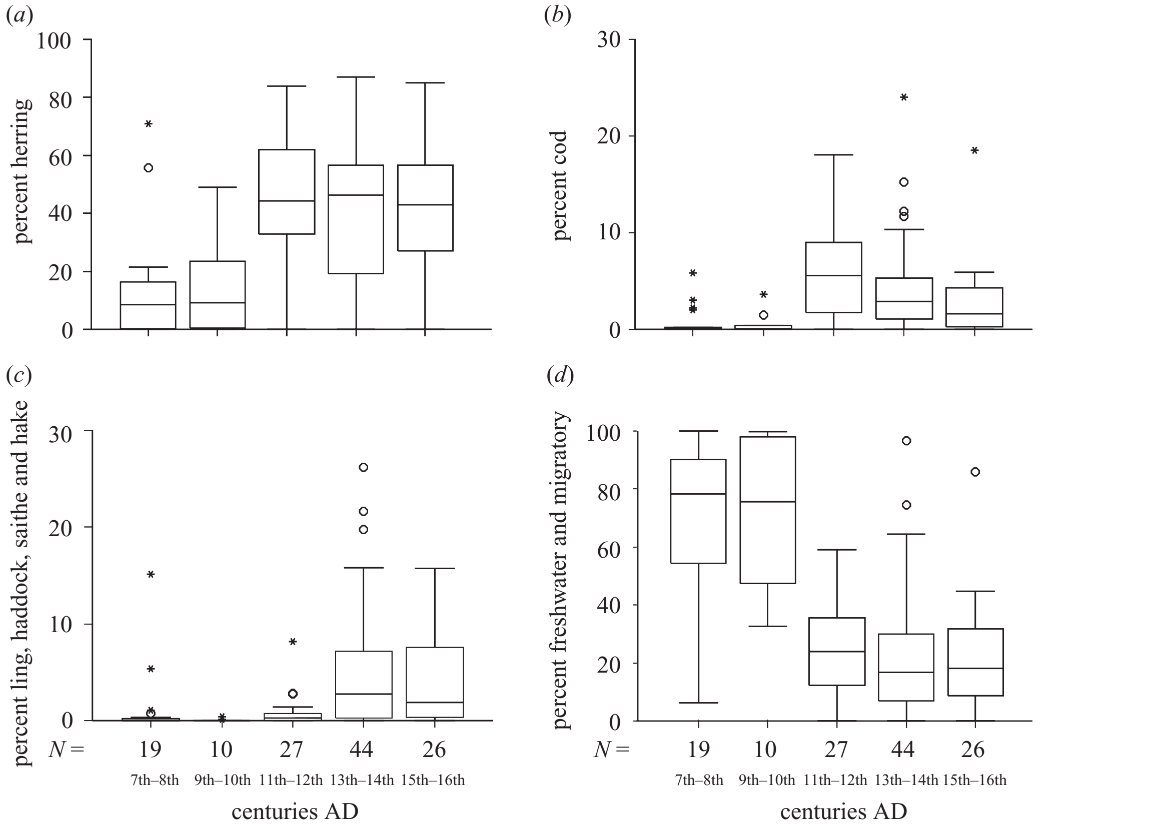

Figure 2. (*a–c*) Boxplots showing the percentages of common marine species in English fish bone assemblages from AD 600 to AD 1600 (based on the number of identified specimens). (*d*) For comparison, the percentage of freshwater and migratory taxa is also shown—based on cyprinids, pike, perch, eel, smelt, salmonids and flatfish (many of which are probably flounder, which enters fresh water).

shore) or estuarine as one might expect (assemblages 8, 9, 65, 85, 112 and 119). These sites were presumably engaged in local subsistence fishing, but it may also be relevant that several of them were proto-urban settlements (see next paragraph).

The chronological patterns in figure 1*a* are largely dependent on the abundance of herring and 'gadids'. The proportions of both show major increases in the eleventh to twelfth centuries (figure 2*a–c*). Herring did occur in seventh- to tenth-century sites, particularly the 'wics' (proto-urban trading settlements) of York, Ipswich, London and Hamwic (Southampton). However, its importance increased significantly in the eleventh to twelfth centuries (Mann–Whitney $U = 35.00$, $p < 0.001$). For cod-like fishes, different species show slightly different chronological patterns. Cod itself was virtually unexploited prior to the end of the first millennium AD. It first appeared as a significant component of the medieval 'catch' in the eleventh to twelfth centuries (Mann–Whitney $U = 41.00$, $p < 0.001$), after which its proportion of the total declined as it was joined by related marine species such as haddock, ling, saithe (*Pollachius virens*) and hake. It is thus not surprising that recent research has shown that there was not even a word for cod in the Anglo-Saxon language of pre-Norman England (Sayers 2002).

The rapidity of these changes can be assessed by focusing on 19 assemblages from around the end of the first millennium that are datable to within *ca.* 100 years (figure 1*b*). These suggest that the increase in herring and cod fishing began between c. 975 and c. 1050 in York, before the end of the tenth century in Northampton, by c. 1050 to 1070 in London, prior to c. 1030 in Southampton, between the late tenth and late eleventh century in Norwich, and by the late eleventh to early twelfth century at Eynsham Abbey (see electronic Appendix A for full references). This 'fish event horizon' thus occurred within a few decades either side of the end of the first millennium AD. It has often been proposed that marine fishing expanded in medieval Europe (Benecke 1982; Jones 1988; Enghoff 2000; Hoffmann 2002; Ervynck *et al.* 2004), but the English evidence presented here demonstrates the date, rapidity and scale of this development.

4. DISCUSSION

The chronology of this increase in marine fishing is all the more remarkable given that data from climate proxies across the North Atlantic and from cored sediments of the North Sea indicate that c. AD 1000 the region was experiencing the mild temperatures of the Medieval Warm Period (Hass 1996; Dahl-Jensen *et al.* 1998; Eiriksson *et al.* 2000; Barber *et al.* 2003; Bradley *et al.* 2003). These conditions were conducive to agricultural expansion on land (Dyer 2002), which one might expect to limit the need for aquatic resources and, most importantly, they probably depressed the local productivity of cod and herring.

The relationship between cod and herring productivity and climate is complex. Both are arcto-boreal species and climate affects them differently in different parts of their ranges. In northern regions, such as around Iceland and the Barents Sea, warm ocean climate is linked to good recruitment of both species (Hamre 2003). However, in southern areas, such as the North Sea and Baltic towards the southern limits of these species' ranges, warm weather depresses production (Brander 2000; O'Brien *et al.* 2000). Such climatic effects arise partly through direct influences on fish physiology, and partly indirectly through species interactions across trophic levels. Broadly speaking, temperature is a proxy for a range of climatic influences affecting fish stock production, including changes in turbulence, wind mixing, water column stability, movement of water masses from place to place, and light conditions.

Although recruitment of both species appears to be similarly affected by sea temperature, the relationships between cod and herring abundance are not entirely straightforward (Hamre 2003). Myers *et al.* (2001), for example, showed that carrying capacity for cod in North Atlantic waters varied 20-fold, declining as ambient temperature increased. However, herring are an important prey species for cod (Hanson & Chouinard 2002), while herring are important predators of cod eggs and larvae (MacKenzie & Visser 2001). Both species also interact with other prey and predator taxa (Hamre 2003; Genner *et al.* 2004). Hence, high abundance of one species may, or sometimes may not, be associated with high abundance of the other. It is likely that, even during extended periods of favourable or unfavourable climate for recruitment, productivity of each species will vary considerably over shorter time and space scales (Genner *et al.* 2004).

Nevertheless, given the known relationships between cod and herring productivity and sea temperature, on balance it can be expected that production of these species was relatively low in the North Sea and Baltic during the Medieval Warm Period. Further north, in the Norwegian Sea, Barents Sea and around Iceland, both herring and cod production can be expected to have been relatively high during this period. Thus climate is only likely to have driven the growth in marine fish exploitation in tenth to eleventh century England if most of the fish remains represent imports from, for example, Norway. A 'butterfly effect' of this kind (in which distant increases in fish availability might have a dramatic effect on English diet and economy) is conceivable but unlikely.

Socio-economic factors and changes to freshwater ecosystems are likely to be more important causal factors. Herring and cod were cured and widely traded by the twelfth century, when unambiguous historical references appear (Holm *et al.* 1996). The earlier rapid increase in their catch that we describe may thus mark the original development of this trade. Christian fasting created the primary demand, although the chronology of fish consumption within fasting practice does remain to be fully explored (Starkey *et al.* 2000; see Barrett *et al.* 2004). Rapid population growth may also have increased the demand for marine fish (Dyer 2002; Hoffmann 2002). Much of this population growth was in towns. The 'urban revolution' and its corollary, the growth of long-range trade in staple goods, were fundamental aspects of the tenth to thirteenth centuries in Europe (Moore 2000). The most important variable, however, may have been declining freshwater fish stocks—owing to siltation from more intensive agriculture, the proliferation of mill dams, increased nutrient loads (from growing urban populations and industries) and inland 'over-fishing' itself (Hoffmann 1996). Clearly, the importance of freshwater fishes decreased in eleventh-century England (figure 2*d*), but it remains to be established whether this was an absolute reduction in the catch or simply a relative decline vis-à-vis marine species.

To conclude, there was a revolutionary expansion of marine fishing in England within a few decades of AD 1000. It was preceded by some use of herring, particularly in proto-urban centres. However, this species became far more important around the end of the first millennium, when it was joined by cod. Other gadids, and the closely related hake, later supplemented these catches—primarily from the thirteenth to fourteenth centuries. There were no further changes in the fish exploited during the later expansion of Britain's fisheries to Iceland and then the North West Atlantic. It is not possible to estimate the absolute quantities caught, but this 'fish event horizon' of c. AD 1000 probably marks the origins of intensive human exploitation of Europe's marine resources. It was probably driven by Christian fasting regulations, population growth, urbanism and declining freshwater fish resources. Unless influenced by a 'butterfly effect', in which increases in cod and herring abundance in northern waters (perhaps around Norway) had a profound effect on English fish consumption, this intensification in marine fishing probably ran counter to climatically determined patterns in fish abundance. As the naissance of intensive, probably commercial, marine fishing, the century between AD 950 and 1050 can now be pinpointed as the ultimate origin of today's fishing crisis and the critical period for future palaeoecological research on marine ecosystems baselines.

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