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Early Medieval Shellfish Exploitation in Northwest Europe: Investigations at the Sands of Forvie Shell Middens, Eastern Scotland, and the Role of Coastal Resources in the First Millennium AD.

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ABSTRACT

Coastal shell middens represent a well-known element of the archaeological record of island and coastal regions across the world and shellfish have been an important resource for subsistence since the mid Holocene. However, the factors that influence shell-fishing remain poorly understood and in many regions investigations into the role of shellfish gathering have often remained focused on prehistoric examples to the detriment of shell middens of later dates. This article reports on the emerging evidence for large-scale exploitation of shellfish during a hitherto understudied period for shell midden archaeology in Northwest Europe: the first millennium AD. The article includes a review of a series of previously unknown large mussel-dominated middens in eastern Scotland, an outline of their chronology and character, including Bayesian modelling of dates, and a synthesis of the emerging evidence for shellfish gathering in Northwest Europe during the first millennium AD. The research represents the first investigation of large-scale early medieval middens in Britain and the first review of their international parallels and the important new information they can provide for the early medieval economy.

Keywords shell middens, coastal archaeology, early medieval, first millennium AD, Scotland, Northwest Europe

INTRODUCTION

Coastal shell middens represent an important, but poorly understood element of the archaeological record of Europe. They survive in a multitude of forms and have great variability in terms of

chronology, size, composition and morphology. Activity at these sites was undoubtedly related to the availability of local shellfish resources, but was also dictated by contemporary social, economic, and environmental factors (Milner et al. 2007, Wickham-Jones 2007). The survival of coastal shell middens shows that for thousands of years, marine molluscs have been exploited as a “readily accessible and easily processed food supply” (Bailey et al. 2013: 1). The skills required for shellfish collection are considered to be “non-specialised”, meaning that whole communities can take part, and in certain parts of Europe the vast shell middens that survive are a testament to the use of coastal resources on a large scale. The study of shell middens is also important because it can provide a range of information, from diet to socioeconomic patterns (Milner et al. 2007; Szabo 2014; Woodman 2013). However, despite enthusiasm for their study in the nineteenth and early twentieth centuries, shell middens are often overlooked in synthetic studies of prehistoric and later historic societies (Milner & Woodman 2007: 101–2). The exception to this is the study of the Mesolithic (particularly the Late Mesolithic of Britain, Ireland and South Scandinavia), where shell middens form one of the major datasets for interpreting northern European late hunter-gatherer coastal societies, and shell middens are often assumed to date to this period (e.g. Mannino & Thomas 2001; Hardy & Wickham-Jones 2009: 38; Milner et al. 2007: 2). In contrast, in more recent periods, shell middens are rarely incorporated into our accounts of society and economy (though see Hardy 2016).

Referring to the lack of focus on shell middens in post-Mesolithic contexts, Milner et al. (2007: 1461) argue that middens created by more recent farming populations are not considered in detail due to the fact that marine foods are seen as a peripheral or marginal contribution to the economy. A number of stereotypes can also colour our view of shell midden resources in later prehistory and later periods (Claasen 1991). One such stereotype includes identifying shellfish as “famine food”, an interpretation that does not capture the diverse roles wild resources tend to play in societies of all periods (Wickham-Jones 2007: 91–2; Woodman 2013). The terrestrial focus of much archaeological discourse has also limited the incorporation of coastal shell midden sites into wider narratives. Finally, many preservation factors have also limited the role that middens have played in interpretive accounts of the past. Many shell middens are found by chance through coastal erosion or incidentally reported as part of excavations focused on other aspects of site chronology and character. Nonetheless, as highlighted in this article, shell middens can provide a crucial dataset for examining the diversity and perhaps specialisation of the economy in later historic (or proto-historic) periods.

Coastal shell middens of the first millennium AD have not to date been widely recognized in northwest Europe, and the most recent syntheses on shell midden research in Atlantic Europe, and

indeed world-wide, have continued the trend of focusing on early prehistoric examples (e.g. Gutiérrez-Zugasti et al. 2011; Horsey & Winder 1992: 60; Bailey et al. 2013). In a new contribution to the study of shell middens in Northwest Europe, a series of excavations and surveys were conducted at the Sands of Forvie, Aberdeenshire, in eastern Scotland, which investigated three large shell middens dating to the first millennium AD, their landscape context, and the possible roles of shellfish in the diet and economy of the early medieval period. There are as yet few direct parallels for the Sands of Forvie middens in Britain and Ireland, but it is hoped that new work in this area can begin to flesh out the picture of coastal exploitation in a hitherto understudied period for shell midden archaeology. While parallels to date are few, specialised coastal economies involving shellfish have been noted in Ireland in the first millennium AD, and in Denmark, a “near-industrial scale” of shellfish gathering has been identified (Andersen 2007). The emerging and often overlooked evidence for first millennium AD shellfish gathering can help explore economy and subsistence during a period that represents an important social and economic watershed in northwest Europe – a period when many of the medieval kingdoms of Europe began to take shape.

ENVIRONMENT AND PREVIOUS ARCHAEOLOGICAL WORK AT THE SANDS OF FORVIE, NORTHEAST SCOTLAND

Prior to the work reported here there were few large-scale shell midden sites known in eastern Scotland, and the ones that had been identified were generally considered to date to the Mesolithic period specifically or prehistoric periods more generally (e.g. Sloan 1982). However, Hardy (2016) has provided a synthesis of the shell midden sites of western Scotland, which shows that gathering of shellfish occurred throughout prehistory and into the modern period. Hardy (2016: 278) suggested that shellfish gathering shifted from a mainstream to a marginal resource over time, pointing to the fact that the later prehistoric to medieval middens are relatively small in scale. The work at the Sands of Forvie outlined below is significant because it suggests a previously unknown scale of shellfish exploitation in Britain during the early medieval period, which challenges some of the existing models of the diminished role of coastal resources after the adoption of agriculture (e.g. Richards et al. 2003).

The Sands of Forvie is an extensive area of shifting sand dunes in northeast Scotland, the fifth largest in Britain, and a designated National Nature Reserve (Ritchie 1983; Scottish Natural Heritage 2009). The movement of windblown sand along this coast, just north of the modern city of Aberdeen, has had a significant impact on human activity in the area, with early dunes established in the south part of the sands from around 2000 cal BC (Hansom 2003; North 1981; Ritchie 1983; 1997). The active nature of the sands has always posed a challenge to settlement in this area – in the medieval period,

the church and settlement of Forvie were overwhelmed by sand in 1413 and by 1680 the whole Parish of Forvie had been abandoned due to sand encroachment (North 1981: 9). It is likely that inundations of sand have affected human settlement in this area throughout prehistory.

Dynamic aeolian landscapes like the Sands of Forvie can bury and preserve archaeological sites to an extent not often encountered in the lowland coastal zones of Europe (Bell & Brown 2008; Cowie 1996; Griffiths & Ashmore 2011; Ralston 1997: 30). Indeed, the Sands of Forvie has long been recognised for its archaeological remains (Figure 1). Extensive assemblages of prehistoric lithics have been collected and recorded since the twentieth century from areas where sand has blown out and re-exposed prehistoric land surfaces, including surface collections totalling thousands of pieces (Hawke-Smith 1980; See also Warren 2005: 173; Tab 1). The lithics appear to date mainly to the Mesolithic Period, but later prehistoric material has also been identified (Warren 2005: 2–11). Upriver to the north, lithic scatters (including Mesolithic and Neolithic material) are recorded at a number of sites suggesting extensive prehistoric use of the lower stretches of the Ythan river (e.g. O'Dell 1960; Saville 2004; Sneddon and Ralston 1984; Sneddon and Shepherd 1985).

Later prehistoric to medieval activity is also well attested in the dune systems at the Sands of Forvie, including extensive Late Bronze Age/Early Iron Age settlement remains comprising hut circles, working areas and cairns (Kirk 1954; Ralston 1997: 31–32; Ralston & Sabine 2000: 147). The area also displays abundant later medieval rig and furrow cultivation ridges and is known to have been used extensively for the procurement of mussels for fishing bait from the late Medieval and Post-Medieval Periods, with the estuary having supplied bait for many of the villages along this stretch of the coastline into the twentieth century (Farquhar 1799; Rust 1845; Warren 2005: 65).

The existence of a range of shell middens and associated occupation material at the Sands of Forvie, along both shores of the Ythan estuary, where extensive mussel beds still exist today, has been recognised for over a century (Dalrymple 1868; Jamieson 1865). Jamieson, for example, observed 'flint flakes and chippings' in association with middens located on both sides of the estuary in the 1860s (1865: 241), and Dalrymple (1868), recorded the excavation of two middens on the north side of the estuary. Survey work by Warren in the late 1990s identified three substantial surviving middens, but more had been identified in the past (e.g. Hawkes-Smith 1980: 497, Fig 1). Warren conducted a topographic survey of two middens resting on the main post-glacial raised beach of the Ythan estuary (Warren 2005: 65–66). Warren's work showed that Midden A survives as a low dome-shaped feature, measuring c. 20 m across, while Midden B is more irregular in shape, measuring c. 35 m in length (Figure 2). The location of these middens on top of, and slumping down the raised shoreline associated with the Main Post Glacial Transgression (MPGT, occurring between 6000–4870

cal BC; Ballantyne and Dawson 2003: 38), suggested to Warren that these two middens were probably Mesolithic in date. The middens were identified as consisting primarily of mussels, with some cockle and winkle shells and burnt stones. Warren (2005: 66) also described a third midden, Midden C, which is located at a lower elevation than the other two middens and slumps down onto the present shoreline of the Ythan estuary (Figure 2). The fieldwork described here targeted these three middens that had previously been surveyed by Warren, as well as their landscape context. At the time of excavation all three middens had been damaged by a range of anthropogenic and natural processes, including a public walking path, rabbit burrowing, and Dalrymple's (1868) nineteenth-century excavations. Midden C, had also been extensively eroded by the river Ythan, and material from this midden was found scattered on the adjacent banks of the river in and above the intertidal zone (SI Figure 1).

ARCHAEOLOGICAL INVESTIGATIONS OF THE SHELL MIDDENS AT THE SANDS OF FORVIE

The fieldwork reported on here was carried out over a period of four years and included the partial excavation and recording of three shell middens. Midden C, which was already exposed by erosion, was targeted first in the spring of 2010, first by cleaning up and recording the eroded and exposed section, and then by excavating three columns through the midden that ranged in width from 1-2 m. Middens A and B were investigated in the autumn of 2010 using a series of small test trenches. The approximate horizontal extent of all three middens was determined by coring along transects using a Dutch auger drilled by hand at 1 m intervals. Investigations of the landscape in the vicinity of the middens was conducted between 2010 and 2014. While the high sand dunes, especially in the vicinity of Midden C, made it impossible to conduct a systematic soil survey throughout the area, coring using a Dutch auger followed up by targeted soil test pitting where the sand dunes were least thick was done to search for buried soils and establish the wider landscape setting of the middens (see Figure 2 for the precise locations of soil survey auger holes and test pits). A topographical survey of the area around the middens was also conducted, and a digital terrain model for the area was generated by integrating the results of a dGPS walkover survey and photogrammetry based on kite aerial photographs (Figure 2). The results of the midden excavations are summarized below, followed by the results of the landscape survey. A more detailed account of the midden stratigraphy is published elsewhere (Noble et al. in press).

Midden C

Midden C, located just a few metres above the present high tide line, was in the poorest state of preservation at the time of the excavation, with a c. 35 m long section heavily exposed to erosion,

and with many shell and charcoal layers visible for a depth of up to 2 m (Figure 3). Coring using a Dutch auger to examine the presence/absence of shells was carried out on a transect extending perpendicular to the eroding face of the midden and established that the dense upper shell midden deposits extended to around 35 m N-S and had a surviving width of around 2–4 m E-W. Analysis was focused on the exposed face of the midden, which was cleaned using spades and trowels and recorded in detail, followed by the excavation of three columns (columns A, B, and C; see Figures 3 and 4).

Column A

Over 2.9 m of deposits, including both anthropogenic midden sediments rich in shells and charcoal, and natural windblown sand layers, were identified in Column A lying on top of compact sands and rounded beach pebbles of a slightly raised beach. The lowest shell midden layer (context 47) consisted of a silty brown sand with a significant shell component (20%), and charcoal. The shells found at this level indicate a lower midden layer of mussels and a small proportion of periwinkle (Table 1). This lower midden layer was covered by around 1 m of windblown sand (contexts 45 and 41) that was largely sterile, with occasional very ephemeral lenses of charcoal. On top of the windblown sand further layers of charcoal, shell and silty sand (40, 39 and 38) were identified below another thick sand deposit (10) and it was on this latter deposit of windblown sand that the upper shell midden levels were identified. The upper shell midden deposits were much more shell-rich, suggestive of more rapid deposition of shells than occurred in the lower midden levels.

The upper shell midden deposits in Column A consisted of deposits around 1 m in depth, with three dense layers of shells interleaved with thin layers of sand. The primary shell midden layer (8) lay on top of a thin charcoal lens (9), was 0.23 m at its thickest, and was mainly composed of mussels, with a small percentage (less than 5%) of periwinkle, cockle and clams (Table 1). This shell midden layer was separated from a second layer by another charcoal lens (7). The secondary shell midden layer in the upper midden (5) was up to 0.16 m thick and was similarly dominated by mussel shells (Table 1). The final shell midden layer in the upper midden (3) was the thickest of the three, around 0.36 m at its thickest, with over 99% mussel shell and a small proportion of periwinkle (Table 1).

Column B

Column B (Figure 4) was excavated to investigate a series of charcoal lenses identified at the base of the upper shell midden layers. These lenses proved to be situated within pits dug into the sand dune upon which the upper midden had formed. At least two pits were identified – small pits less than 0.5 m in diameter with shell and charcoal fills. Above these features in the upper midden layers was a

similar series of deposits to that found in Column A. These included at least three distinct shell midden layers (21, 20 and 16), interspersed with discrete sand layers.

Column C

The most illuminating column dug during the 2010 excavations was Column C (Figure 4), which was excavated to investigate a pit identified in the eroding section together with a concentration of fire-cracked stones found on top of the sand dune deposits that underlie the upper midden. The lowest layers identified in Column C lay on top of raised beach deposits and consisted of a basal layer of charcoal and burnt stone (44), and a layer (42) with a high shell component (c. 50%) (mussels and periwinkle, Table 1). Above these lower midden layers lay a thick deposit of windblown sand identical to that identified in Column A. Within the windblown sand deposits a large fire pit (31) was identified (Figure 4; SI Figure 2). The pit measured around 1.15 m N-S by 0.75 m E-W. The upper matrix of the pit consisted largely of heat affected stones (32), including examples of *in situ* fire-cracked stones. Within and just above the stones a yellow sand matrix contained numerous mussel shells, including a notable number of whole shells. Below the fire-cracked stones was an *in situ* burnt deposit consisting of a compact, nearly pure charcoal layer, including large charred twigs and small branches and a lower fill of partially burnt peat. In Column C the upper midden had the same general character as revealed elsewhere, with around 0.7 m of shell midden deposit sandwiched between the modern topsoil and lower sand dune deposits (Figure 4). Within the upper midden deposits details were revealed about shell discard practices on the midden – within the fill two nested mussel shells were found, with a large periwinkle shell clasped inside (SI Figure 3).

Midden A

Midden A is located c. 200 m from Midden C and sits on top of the main MPGT raised beach (Figures 1 and 2). The densest part of the midden is above the ancient shoreline and extends over an area 20 m NW-SE by 10 m NE-SW based on topographic survey, but the midden layers also slump down over the face of the shoreline for a distance of around 10 m (Figure 2). An auger survey examining presence/absence of shell remains carried out along a series of transects, together with the excavated test pits, confirmed the broad extent of the midden visible through topographic survey. The soil auger survey of the wider landscape (Figure 2) did not reveal any similar dense midden layers in the vicinity of Midden A. Four test pits (SQ1–4) were laid out in a transect across Midden A from near the uppermost part of the midden towards the shoreline of the River Ythan (SI Figure 4). Located at the top of the midden mound, SQ1 revealed the densest midden deposits, comprising two thick layers of shell, charcoal and fire-cracked stone, with examples of nested shells similar to

those found at Midden C. The upper (108) and lower (112) shell midden layers, which were around 0.4 m and 0.36 m thick respectively, were separated by two c. 0.1 m thick layers of windblown sand with a lense of charcoal (110) between them. These midden deposits lay on top of a deep deposit of windblown sand within which there was evidence for pit-digging (SI Figure 5). Further examples of pit-digging were found in SQ2. The pits were all of similar dimensions, less than c. 0.4 m wide, and each contained thin lenses of degraded shell with occasional charcoal flecks.

Midden B

Midden B is an irregularly shaped mound or series of mounds. The length of the midden, defined by topographic survey and by augering along a series of transects, is around 35 m NW-SE and around 10–15 m wide NE-SW, with the south-westerly portion of the mound eroding down the edge of the MPGT raised beach (SI Figure 6). The midden is mainly comprised of shell layers of a similar character to that found at Middens A and C, with mussel dominating much smaller amounts of periwinkle and the occasional cockle (Table 1). Midden B differs in character from Middens A and C, in that it consists of generally thinner lenses of shell and includes a small quantity of animal bone, but in the densest areas of shells three main layers of shell were identified of a similar character to the upper middens of Middens A and C. The midden layers at Midden B reached a maximum depth of 0.3 m (SI Figure 7), and hand coring using a Dutch auger with two 1 m-long extensions confirmed that the midden rested on a large sand dune. Unlike Middens A and C, no deeper deposits below the windblown sand were identified. Multiple fire-pits were cut into the lower sand deposits and through the midden layers (SI Figure 8). One of the best-defined features was a shallow pit (214), up to 0.1 m in depth, which had a lower fill full of charred roundwood twigs and small branches. Pieces of antler and a small number of animal bones were recovered from Midden B (Table 2). The animal bones comprised fragments of cattle bone and the antler was from red deer. The presence of canid gnawing on bones demonstrates the presence of dogs at the site. Two fragments of bone show evidence of butchery (the cattle ulna and one unidentified rib fragment) suggesting that there was small-scale consumption of animals at the site.

THE WIDER LANDSCAPE

It is difficult to determine the precise relationship of the middens to the first millennium AD shoreline, because there are unfortunately no detailed sea-level models for the area (Smith et al. 1983). However, glacio-eustatic sea-level rise in the area over the last two centuries has been minimal (c.1 mm per year) and any rise since the early medieval period is likely to have been countered by glacio-isostatic rebound in this region. Therefore, the sea level in the area during the

early medieval period is likely to be very similar to today. However, the course of the Ythan estuary does change position over time, and the present course of the Ythan is different to that only 50 years ago, as evident in historic mapping and aerial photographs. The middens currently lie above the limits of the high tide in the estuary today, but Midden C lies only just above the high tide mark, and the fact that parts of Midden C have clearly been eroded make it likely that it was reached during storms and/or by the altering course of the estuary through time. Thus, although we do not know the exact position of the middens in relation to the first millennium AD shoreline, the fact that the high tide line is near the current middens and that shell processing tends to occur close to the sites of procurement or landing (e.g. Hardy et al. 2016: 29), it is probable that the middens were as close to the contemporary shoreline in the early medieval period as they are today.

Geophysical survey and a soil survey using a Dutch auger and soil test pitting has shown relatively little anthropogenic activity in the immediate vicinity of the middens, although the depth of sand deposits in many areas poses significant challenges to reaching buried palaeosols (Figure 2). Test pitting around 200 m northwest of midden B revealed thick, homogenous, sandy buried plough soils (buried Ap horizons) dating from the early Iron Age, and these soils suggested significant inputs of windblown sand were occurring already in the 8th–4th century cal BC (Table 5). Abandonment of this area to agriculture during the Iron Age to early medieval period may have followed a similar trajectory to the abandonment of Forvie village in 1413, in which people had been surviving small sand events for many years but were finally forced to abandon the village after a major influx of sand (Ralston 1997; Ritchie 1997). The thick deposits of windblown sand over the lower middens of Middens A and C suggest that cultivation in the immediate vicinity of the middens would have been difficult. The extensive auger survey conducted in 2014 confirmed that the landscape around the middens was entirely covered by deposits of windblown sand, which in places appeared to cover post-glacial soils, but no buried ploughed soils, further midden layers, or settlement evidence was found in the vicinity of the middens with the exception of one very ephemeral turf-built structure that stratigraphically overlay a large sand dune, and was probably medieval or later in date (Figure 2; unfortunately no material suitable for radiocarbon dating was recovered from flotation samples from this structure). The nearest possible contemporary settlement to the middens is located 3.5 km to the north at Cluny Cottages (Figure 1), where a settlement consisting of turf-built structures, including one that resembles early medieval longhouses (e.g. Carver et al. 2012) has been located, but absolute dating will require further fieldwork. It appears therefore that the middens were relatively isolated in terms of contemporary settlement, but they suggest long-term, intensive shellfish gathering in what was a marginal landscape for farming.

RADIOCARBON DATING OF THE MIDDENS

Six radiocarbon dates were obtained from charcoal deposits in Midden C and one date each from Middens A and Midden B (Tables 3 and 4) (SI Figure 9). All the samples were single-entities of charcoal from short-lived wood branches and were submitted to the Scottish Universities Environmental Research Centre to be measured by Accelerator Mass Spectrometry (AMS). A Bayesian approach was adopted for the interpretation of the chronology of Midden C given the range of dates and its deeper stratigraphic sequence (see Buck et al. 1996). This represents the first time that a Bayesian modelling has been applied to a shell midden in Britain.

Bayesian modelling was conducted using OxCal v4 (Bronk Ramsey 2009) and the internationally-agreed calibration curve for the northern hemisphere, IntCal13 (Reimer et al. 2013). The model relationships were illustrated using a standard Harris matrix, and the transition between the earlier and later midden activity (*early/late Use*; SI Figure 10) was modelled as two discrete boundaries, which allowed for the potential of a hiatus. Furthermore, the date of the massive sand blow on which hearth setting 33 was placed was estimated in the model (*Sand blow*; SI Figure 10). The results of the modelling are interpretative and are presented in *italics* to make them clearly stand apart from any dates that are from simple calibration of single radiocarbon ages.

The model shows good agreement between the radiocarbon dates and the recorded stratigraphic positions of the samples within the midden ($A_{\text{model}}=87$). The low number of dates does not provide a precise model (Steier and Rom 2000), but provides a basic framework for the chronology of Midden C. The model estimates that the lower midden was forming in *cal AD 85–535 (95% probability; Figure 5; start: Midden C)* and probably in *cal AD 280–430 (59% probability)*. Overall deposition of material in the upper midden began in *cal AD 640–880 (95% probability; Figure 5; bottom: upper midden)* and probably in *cal AD 720–840 (68% probability)*. The midden ceased being used in *cal AD 775–1000 (95% probability; Figure 5; end: Midden C)* and probably in *cal AD 805–915 (68% probability)*. The deposition of windblown sand took place in *cal AD 730–880 (95% probability; Figure 5; Sand blow)* and probably in *cal AD 770–850 (68% probability)*. Deposition in the upper midden lasted for *1–310 years (95% probability; SI Figure 11; span: later Use)* and probably for *1–135 years (68% probability)*. The radiocarbon date from just below the sand blow is statistically consistent with the three dates from above ($T'=3.1$; $v=3$; $T'(5\%)=7.8$; ff. Ward & Wilson 1978),

suggesting the relatively rapid deposition of material from just below the sand blow through to the uppermost portion of the sequence.

Only one radiocarbon date is available for Midden B. This came from small roundwood charcoal in shallow pit 214, and shows that the midden was in use in the period cal AD 420–580 (95% probability; SUERC-38444: 214; Fig. 13), broadly contemporary with the lower midden levels at Midden C. Again only one date is available for Midden A. This came from charcoal lens 110, which lay between two sand lenses that were in turn sandwiched by the upper and lower shell midden deposits, and the date of cal AD 770–990 (95% probability; SUERC-38443: 110; Fig. 13), was broadly contemporary with the latest phases of Midden C.

DISCUSSION

When excavations at Midden C began, it was presumed the middens at the Sands of Forvie were prehistoric in date. The radiocarbon dating results provide a significant addition to our knowledge of shellfish gathering in eastern Scotland in the first millennium AD and can help us reassess the potential role of coastal resources in later periods in Northwest Europe. More generally across Europe, the number of shell midden deposits is potentially vast, though most areas have not been subject to detailed coastal surveys (Gutiérrez-Zugasti et al. 2011). Milner and Woodman (2007: 101) suggest that in excess of around 200 shell middens survive on the coasts of Ireland and a survey of Scotland's national monument records conducted as part of this study has shown that a similar number are known to exist in Scotland (SI Figure 12). However, in Scotland and Northwest Europe more generally the best known shell midden sites are prehistoric in date. In Scotland the most intensively studied are the Mesolithic shell middens on the west coast and to a lesser extent the large Mesolithic-Neolithic shell middens found on the former shores of the Firth of Forth on the east coast (Sloan 1982; Hardy 2013; Mellars 1987).

A number of middens have been dated to later periods, but their significance is only beginning to be explored (Hardy 2013: 133; 2016), as is the evidence for shellfish exploitation in general in the first millennium AD. Much of the current evidence relates to the northern Scottish island of Mainland Orkney, where a number of early medieval shell-bearing sites dating to the mid to later first millennium AD have been investigated on the west coast, including the Point of Buckquoy, Brough Road, and Saevan Howe, all near the important medieval settlement of Birsay (Brundle et al. 2003; Colley 1983; Ritchie 1977). However, the middens in Orkney have generally been found within a domestic context and have been interpreted as small-scale domestic gathering of shellfish for

consumption or bait (e.g. Evans & Spencer 1977; Rackham 1989: 260; Ritchie 1977: 191; Wheeler 1977, 214). At the coastal site of Quoygre, on Westray, Orkney, midden deposits in a farm mound dating to the ninth- to sixteenth-century AD, as well as in a coastal midden dating to the eleventh to thirteenth century AD, contained shellfish remains – mainly limpets, but also periwinkles, cockles, mussels, whelks, cockles, clams, scallops, cowries and razor shells (Milner and Barrett 2012). At this site, shellfish were interpreted as fish bait on the basis of analogy to Fenton's (1992; 1978: 528, 542, 585-6) ethno-historic research on shellfish as bait (Simpson et al. 2005: 368), as well as on the basis of a concurrent increase in fishing and consumption of marine protein from the top of the food chain, based on faunal and isotopic evidence from Orkney (Milner et al. 2007). In addition, it was pointed out that the slightly smaller limpets and different mix of taxa from the shell dumps in the later phases of the farm mound might have been consumed (Milner and Barrett 2012: 113). It should be pointed out, however, that most of the middens from Orkney come from settlement sites and are often only partially excavated (indeed midden sites in Scotland are rarely fully excavated or the focus of concerted research programmes). We would also argue that the Orcadian sites should be classified as shell-bearing sites rather than shell middens *per se* (see Gutiérrez-Zugasti et al. 2011: 72 for a discussion on this distinction). The increased evidence for fishing in the Viking Age may suggest that shellfish from this period were largely used for bait (Barrett et al 1999; 355), but the role of shellfish in the earlier first millennium AD phases of Orkney seems less secure and would repay further investigation and excavation.

In the rest of Scotland shellfish have been found in abundance on other coastal settlement sites, notably at the Iron Age to high medieval site of Bornais on the isle of South Uist, in the Outer Hebrides, where they were interpreted as food for human consumption (Sharples 2005a: 146-147; Sharples 2005b: 159-161; Sharples 2012: 228; Sharples & Light 2012: 201-203). However, few first millennium AD shell midden sites (as opposed to shell-bearing sites) have been identified. In western Scotland, Hardy (2013: 130; 2016: 276) has suggested that periwinkle-dominated shell middens may be medieval in date and she identified a series of middens found in association with monastic or religious sites at Ashaig and Skeabost on Skye, Inverie at Knoydart, Finlaggan in Islay, and Church Cave on Rona. However, few of these sites have been directly dated or investigated in detail. In Britain more generally, Mays and Beavan's (2012) investigation of diet in early Anglo-Saxon England in the fifth to seventh centuries concluded that in general it was based primarily on terrestrial foods. Similarly, in Scotland, isotopic studies of pre-Viking Age early medieval populations suggest limited marine contributions to diet prior to the ninth century AD (e.g. Barrett & Richards 2004; Curtis-Summers et al. 2014). In Anglo-Saxon England, however, shellfish remains have been found in a variety of contexts, including early Saxon deposits at Bishopstone, Sussex, and Middle Saxon

contexts at Lyminge, Kent (Campbell 2010; Mays and Beavan 2012: 872). At Lyminge, the shellfish remains were dominated by mussels. However, in these contexts the shellfish remains were not found concentrated in large middens, but were more scattered deposits of shells. Larger-scale shell gathering is known in Roman and Saxon contexts along the waterfront in London, and some Roman examples appear to indicate evidence for the farming of these resources. A small number of sites appear to represent the collection of millions of oysters, but evidence of this type has not been identified on a large-scale elsewhere in England (Horsey & Winder 1992: 61). Apart from sites like Lyminge, shell-fish gathering has not been commonly identified in Anglo-Saxon England, though there is some evidence for increases in intertidal fishing from the 8th century AD onwards (Rippon 2000; 2010).

A number of coastal shell midden sites associated with early medieval contexts are known in Ireland, but dating is generally poor (O'Sullivan et al. 2014: 116). Some of these sites appear to have been settlements, perhaps seasonal in nature, with relatively small deposits of shell associated (e.g. Doonloughan Co. Galway: Murray and McCormick 2012). These show evidence for associated occupation in the form of surfaces, hearths, finds including metalwork and beads, and occasionally more substantial structures, and they therefore differ significantly from the Sands of Forvie examples (e.g. Murray 2007: 128–31). Larger deposits of shell are also known and some of these may be associated with monastic settlements (Mallory & Woodman 1984; O'Sullivan et al; 2014: 116–17). Extensive oyster middens are known from Cork in Ireland, including at Ballintubbrid, where an oyster midden c. 150 m in length and over 1.5 m thick has been identified. The upper layers of the midden at Ballintubbrid date to 820-1030 cal AD, broadly contemporary with the middens at Forvie (Milner & Woodman 2007: 103). Some Irish middens also suggest more specialized processes were associated with shell collection. For example, the occurrence of broken dog-whelk shells at sites such as Dooley, Co Donegal, indicates the production of purple dye and some of these sites also appear to have been involved in metalworking and other craft production activities (Murray 2007: 130–131; Murray & McCormick 2012).

In northern Europe more generally, the closest parallels for the shell middens at the Sands of Forvie are the Iron Age-Viking Age middens of Denmark. Denmark has the highest concentration and most intensively studied shell midden sites in northern Europe, most of which have been found along the coasts of east and south-west Jutland and Zealand. Here again the most intensive studies have been on earlier prehistoric middens. However, massive mussel middens appear in the Early Iron Age in the second half of the first millennium BC and generally occur until the later first millennium AD. Their size varies greatly, with some examples up to 1 km in length and 20 m in width, but most consist of

shell layers generally not thicker than 1 m in depth (similar to the upper middens of Forvie). These middens are dominated by mussels, with some cockle, periwinkle and oyster shells. Circular concentrations of shells, charcoal and fire-cracked stones found within the middens have been interpreted as hearths or fire pits for the cooking, drying or smoking of mussels (Andersen 2007: 40–41). Similar middens have also been found at several coastal locations in northern Germany (Anger 1974).

Understanding the role of the large shell middens at sites like the Sands of Forvie requires a detailed consideration of the character of the shell-bearing deposits and the cultural context of the midden formation. The dating from Forvie shows that the three major middens investigated thus far are all first millennium AD in date. While midden sites can vary in date and composition horizontally as well as vertically (e.g. Clemente-Conte et al. 2013: 79-80), the combination of stratigraphic excavation, recording of eroding sections, and test pitting across each mound provides a secure chronology and characterization of the Forvie middens. More specifically, the radiocarbon dates from all three middens included samples that targeted primary layers of the middens and in the case of Midden C in particular, the dating, stratigraphy and Bayesian modelling provides a secure first millennium AD chronology. In terms of composition, in all cases, where identifiable, the middens were overwhelmingly dominated by mussels, the dominant species found in the estuary today (See Table 1 for detailed analysis of Midden C). Midden B was of a slightly different character to Midden A and Midden C, consisting of thinner layers of shell and the occasional fragments of animal bone, and the dating suggests this midden started later than the other two. However, Midden B has also revealed very similar types of activity to that at Middens A and C – the construction of fire pits for the cooking of mussels and the creation of shell midden layers. At Midden B the overall midden may have been created over a relatively short period of time (as suggested for the upper part of Midden C) and perhaps by smaller numbers of people than the other two larger and deeper middens.

At all three midden sites concentrations of fire-cracked stone were found in the midden layers and within pits dug into the midden and into the underlying sand deposits. These pits were of a similar character, with fills of charcoal, shell, and in some cases evidence for re-cutting. The large fire pit (feature 31) found in Midden C provides an illuminating example of one of the pits. This feature consisted of lower fills of peat and charred wood and an upper deposit of fire-cracked rock, with a distinct layer of shell above, including whole shells. The composition of these fills provides strong evidence for the cooking of mussels within the fire pit. The recurring presence of pits with charcoal suggests that the middens were created in the process of cooking mussels rather than being the outcome of collecting mussels for other purposes, such as bait for fishing. The presence of fire-pits

more generally also mitigates against their use for bait – there is no evidence that bait in later periods was cooked (Fenton 1992). The absence of fish bones in the midden deposits, which were highly calcareous and provided good preservation conditions for bone, also suggests that this was not a fishing site (e.g. in contrast to some Viking Age middens in Orkney; Harland & Barrett 2012). None of the other pits identified at Midden C were as well preserved as fire pit 31, but may simply represent pits that were emptied during the collection of the cooked shellfish, with the stone and charcoal perhaps also collected for reuse in other pits. Fire pit 31 had also probably been cleared out on a previous occasion, but in its last use the charcoal, heated stones and some of the shellfish had for whatever reason been left *in situ*. From ethnographic accounts, Waselkov (1987) suggests that the main ways of cooking shellfish without prior removal of shell are either by baking, boiling or steaming, but the different methods are difficult to tell apart archaeologically (Parmalee & Klippel 1974; Thoms 2009; Waselkov 1987: 100–105; See also Hardy et al. 2016).

The upper shell midden deposits at Midden C, which were around 1 m in depth, and the substantial layers in Midden A, both with large-quantities of fire-cracked stone and the repeated occurrence of fire-pits, suggest that intensive processing and cooking of mussels took place at the Sands of Forvie in the second half of the first millennium AD. The Iron Age and early medieval coastal shell middens in Denmark, which, like the Sands of Forvie examples, are composed mostly of mussels, feature a number of hearth or fire pit features closely comparable to those found at the Sands of Forvie (Andersen 2007: 40–41). These features are characterised by circular concentrations of charcoal, shell, and fire-cracked stone. Andersen (2007: 41) also interprets these as cooking pits, or more tentatively suggests they may have been related to the drying or smoking of the mussels. The latter interpretation highlights that mussels can be preserved, providing greater economic potential for these coastal resources, and a possible explanation for the fact that they had clearly been gathered intensively on such a large scale.

How might we interpret these middens? While Wickham-Jones (2007) critiques the stereotyping of shellfish as famine food, the location of the middens in a landscape where agriculture was under constant threat from sand incursions could suggest that these were the expedient use of a resource in times of stress. The eighth–ninth centuries AD, when the most intensive shell midden gathering seems to have taken place, is also a period when the impacts of Viking raids were keenly felt in northern Scotland (Graham-Campbell & Batey 1998). Wider social and economic influences could have led to the use of shellfish to replace or supplement other means of subsistence in the later first millennium AD in northeast Scotland. However, the substantial size and duration of the middens at

the Sands of Forvie is more suggestive of focused, specialised use of a marine resource than expedient use of shellfish at times of stress.

The intensity of shellfish gathering may suggest other purposes for the middens. In Denmark, Andersen (2007) interprets the massive mussel middens not as evidence for settlement or due to short-term crises such as famine, but as specialised coastal sites used for concentrated periods of time for the gathering and processing of mussels. Similar middens in north Germany have also been interpreted as intensively used seasonal sites (Anger 1974: 55). The Danish middens in particular reached proportions that suggest very intensive gathering of shellfish resources:

The size and cubic content of these middens demonstrate a comprehensive and intense gathering of mussels nearly on an “industrial scale”, which must reflect a huge social enterprise and organisation, not only in the gathering and processing of the mussels, but also in the procurement of the large amounts of firewood and charcoal needed for the cooking activities (Andersen 2007: 41).

While smaller than some of the Danish midden sites, the scale of shellfish gathering at Sands of Forvie in eastern Scotland was still clearly very substantial, and, like the Danish examples, the Forvie middens represent a significant investment in labour. Citing ethnographic examples from Senegal, Hardy et al. (2016: 28) suggest that middens dominated by single species tend to be for the production of shellfish resources for trade. The scale and intensity of the almost exclusive mussel-gathering evident at the Sands of Forvie – in Middens A and C in particular – suggest very intensive phases of midden creation in the late first millennium AD. Like the Danish and north German middens, and the ethnographic evidence from Africa highlighted by Hardy et al. (2016), the intensity of use and the collection of a single resource suggests that the shellfish may have been for wider distribution. At the Sands of Forvie the gathering came at a time when the landscape of the Sands of Forvie was covered by very extensive windblown sands and clearly the area in the vicinity of the middens was not used for agriculture. There are also few indicators of contemporary settlement or use of the landscape in the immediate vicinity. The lack of contemporary occupation in the near vicinity suggests that the Forvie middens were specialised coastal sites that people may have travelled some distance to exploit and the resource traded beyond the locality where the middens were created.

The Sands of Forvie shellfish gathering is certainly likely to have occurred on a scale that outstripped the needs of individual family groups. For example, the upper midden deposits at Midden C may contain at least 140 m³ of shells and the middens were clearly truncated (as evidenced at Midden C by the large eroding section – See Figure 4) and therefore larger in the past. Indeed, the surviving

evidence from middens is always likely to be only a very partial picture of what was collected in the past (Hardy 2013: 132-133). Given the quantity of shells, and large size of these middens (in a British and Irish context at least), the mussels in the middens at the Sands of Forvie may have been gathered to meet the needs of a larger community or perhaps even gathered and processed as an important commodity for trade. If mussels were preserved by cooking, drying or smoking, the mussels would also have had a longer lifespan and even greater economic potential (see Waselkov 1987: 105–109; Hardy et al. 2016). The processing of mussels on this scale might even indicate their use in tribute or render. For example, the range of products supplied to elites in Anglo-Saxon England could be diverse and could include coastal or riverine resources (Woolf 2007: 24). Shellfish may have also been an important commodity in a developing Christian context as an important dietary requirement during fast days (Barrett et al. 2004). The middens might even represent the commoditisation of a locally available resource in order to tap into emerging local markets (e.g. the economic networks that supported Christian monasteries), or perhaps even the emerging longer distance markets to which new trading centres in northern Europe – especially from the eighth century AD onwards – were giving access (e.g. Hamwic, York, Dorestad, Ribe, Hedeby) (e.g. Clarke & Ambrosiani 1995; Verhaeghe 2005; Willemsen & Kik 2012). Discussions of economy and trade in an early medieval context have often neglected evidence of specialised food production in favour of long-distance elite trade (Campbell 1996: 81, 87), or mercantile activity (Woolf 2007: 36). The Sands of Forvie middens and the examples in Denmark and north Germany can perhaps provide insight into the emergence of more specialised economies in the first millennium AD, focussing on locally abundant resources, of a character rarely documented. Whatever the precise interpretation of the middens, it is clear that the exploration of coastal resources has much to tell us in a period where the potential of shell midden archaeology is only just beginning to be revealed.

How shell midden sites such as the Sands of Forvie fitted into wider patterns of coastal resource use remains to be fully resolved. In Scotland, fish bone assemblages are very rare prior to the Viking Age and largely unknown in a Mainland context. In Anglo-Saxon England, fish bone assemblages are also uncommon and neighbouring continental evidence from Belgium, France, the Netherlands and Baltic regions is similarly meagre (Barrett 2016: 251). In Scandinavia by contrast, limited marine fishing was widespread from the mid first millennium AD. In all regions around the North Sea there was an upsurge in fishing in the later first millennium AD and marine fish was a trade commodity that grew in tandem with developing market towns and powerful central places, before rising significantly at the turn of the first millennium AD with the emergence of more intensive marine fisheries (Reynolds 2016). In Scotland, it may have been a Scandinavian influence in the later first millennium/early second millennium AD that led to the rise in interest and exploitation of coastal resources (Barrett &

Richards 2004: 249; Barrett et al. 2011), but the evidence for use of fish and shellfish outside the main areas of Scandinavian influence has remained opaque until now. Studies such as this one at the Sands of Fovie can perhaps prompt a broader evaluation of the use of coastal resources in early medieval Northwest Europe, and more specifically in areas where this evidence has traditionally been thin on the ground.

CONCLUSIONS

Shellfish gathering has clearly had important roles in the development of human societies throughout the world (Coddling et al. 2014: 145), yet studies of the archaeological traces of this practice have often been focused on prehistoric examples and in particular the earlier manifestations of coastal exploitation. Nonetheless, the study of shell gathering from later contexts is slowly beginning to develop, and in Europe the factors that may have influenced these practices can begin to contribute to the consideration of the rise of social complexity during the historic period, when more hierarchical forms of society and economy began to emerge. The new evidence from eastern Scotland can perhaps prompt a new chapter in the study of shell middens in Northwest Europe and a re-evaluation of the role of coastal resources in the early medieval economies of Northwest Europe.

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REFERENCES

- Andersen, S. H. 2007. Shell middens (“Køkkenmøddinger”) in Danish prehistory as a reflection of the marine environment. In Milner et al 2007: 31–45.
- Anger, K. 1974. Untersuchungen an eisenzeitlichen Muschelhaufen an der Flensburger Förde. *Offa* 30: 55–59.

- Bailey, G. N., Hardy, K. and A. Camara. 2013. Shell Energy: An Introduction. In *Shell Energy: Mollusc Shells as Coastal Resources* (G. N. Bailey, K. Hardy and A. Camara, eds.): 1–6. Oxford: Oxbow Books.
- Ballantyne, C.K., and A.G. Dawson. 2003. Geomorphology and Landscape Change. In *Scotland After the Ice Age: Environment, Archaeology and History 8000 BC - AD 1000* (K.J. Edwards and I.B.M. Ralston, eds.): 109–125. Edinburgh: Edinburgh University Press.
- Barrett, J. H., Nicholson, R. H. and R. Ceron-Carrasco. 1999. Archaeo-ichthyological Evidence for Long-term Socioeconomic Trends in Northern Scotland: 3500 BC to AD 1500. *Journal of Archaeological Science* 26: 353–388.
- Barrett J.H., Orton D., Johnstone C., Harland J., Van Neer W., Ervynck A., Roberts C., Locker A., Amundsen C. and Enghoff I.B. 2011. Interpreting the expansion of sea fishing in medieval Europe using stable isotope analysis of archaeological cod bones. *Journal of Archaeological Science* 38(7): 1516–1524.
- Barrett, J. H. & M. P. Richards. 2004. Gender, Religion and Economy: New Isotope and Radiocarbon Evidence for Marine Resource Intensification in Early Historic Orkney, Scotland, UK. *European Journal of Archaeology* 7(3): 249–271.
- Bell, M. & Brown, A. 2009. *Southern Regional Review of Geoarchaeology: Windblown Deposits*. Fort Cumberland: English Heritage. Research Department Report Series no. 005-009.
- Bronk Ramsey C. 2009. Bayesian analysis of radiocarbon dates. *Radiocarbon* 51(1): 337–60.
- Brundle, A., Lorimer, D. H. & A. Ritchie. 2003. Buckquoy revisited. In *Sea Change: Orkney and Northern Europe in the Later Iron Age AD 300–800* (J. Downes and A. Ritchie, eds.): 95–104. Angus: Pinkfoot Press.
- Buck, C. E., Cavanagh, W. G. and C. D. Litton. 1996. Bayesian approach to interpreting archaeological data. Chichester: John Wiley & Sons, Ltd.
- Campbell, E. 1996. Trade in the Dark Age West: a peripheral activity? In *Scotland in Dark Age Britain: The Proceedings of a Day Conference held on 18 February 1995* (B. E. Crawford, ed.): 79–91. Aberdeen: Scottish Cultural Press.
- Campbell, G. 2010. *Assessment of the archaeological potential of the sieved middle Saxon molluscs sieved from Lyminge, Kent*. Unpublished report: University of Reading.
https://www.reading.ac.uk/web/FILES/archaeology/Campbell_2011_Mollusc_assessment_report.pdf

- Carver, M.O.H., Barrett, J., Downes, J. and Hooper, J. 2012. Pictish-period byre-houses at Pitcarmick and their landscape: investigations 1993-5. *Proceedings of the Society of Antiquaries of Scotland* 142: 145–199.
- Claassen, C. 1991. Normative Thinking and Shell-Bearing Sites. *Archaeological Method and Theory* 3: 249–298.
- Clarke, H. and Ambrosiani, B. 1995. *Towns in the Viking Age*. Leicester: Leicester University Press.
- Clemente-Conte, I., Ballbè, E. G. and García-Díaz, V. 2013. Prehistoric Shell Middens on the Caribbean Coast of Nicaragua: Food Production, Structures and Site Formation'. In Bailey et al. 2013: 69–82.
- Codding, B. F., Whitaker, A. R. and D. W. Bird. 2014. Global Patterns in the Exploitation of Shellfish, *The Journal of Island and Coastal Archaeology* 9(2): 145–149
- Coles, J.M., and Taylor, J. L. 1969. The Excavation of a Midden in the Culbin Sands, Morayshire, *Proceedings of the Society of Antiquaries of Scotland* 102: 87–100.
- Colley, S. M. 1983. Marine resource exploitation. In Hedges 1983: 111–113.
- Cowie, T.G. 1996. Torrs Warren, Luce Sands, Galloway. *Transactions of the Dumfriesshire and Galloway Natural History and Antiquarian Society* 45: 44–71.
- Curtis-Summers, S., Montgomery, J. and Carver, M. 2014. Stable Isotope Evidence for Dietary Contrast Between Pictish and Medieval Populations at Portmahomack, Scotland. *Medieval Archaeology* 58(1): 21–43.
- Dalrymple, C. E. 1868. Notes on the Excavation of Two Shell-mounds on the Eastern Coast of Aberdeenshire. *Proceedings of the Society of Antiquaries of Scotland* 6: 423–426.
- Dobney, K. and Reilly, K. 1988. A method for recording archaeological animal bones: the use of diagnostic zones. *Circaea* 5, 79–96
- Evans, J. G. and P. Spencer. 1977. The mollusca and environment, Buckquoy, Orkney. In Ritchie 1977: 215–219.
- Farquhar, A. 1799. The Parish of Slains, *The Statistical Account of Scotland, 1791–99*: 275–286. Edinburgh
- Fenton, A. 1978. *The Northern Isles: Orkney and Shetland*. East Linton, Scotland: Tuckwell Press.

- Fenton, A. 1992. Shellfish as bait: The interface between domestic and commercial fishing. In *Scotland and the Sea* (T. C. Smout, ed.): 137–153. Edinburgh: John Donald.
- Graham-Campbell, J. and C. E. Batey. 1998. Vikings in Scotland: An Archaeological Survey. Edinburgh: Edinburgh University Press.
- Griffiths, D. and P. Ashmore. 2011. Introduction: Aeolian Archaeology: The Archaeology of Sand Landscapes in Scotland. In *Aeolian Archaeology: the Archaeology of Sand Landscapes in Scotland* (D. Griffiths and P. Ashmore, eds.). *Scottish Archaeological Internet Reports* 48: 1–8.
- Gutiérrez-Zugasti, I., Andersen, S. H., Araújo, A. C., Dupont, C., Milner, N. & A. M. Monge-Soares. 2011. Shell midden research in Atlantic Europe: State of the art, research problems and perspectives for the future. *Quaternary International* 239: 70–85.
- Hansom, J.D. 2003, Forvie. In *Coastal Geomorphology of Great Britain*, Geological Conservation Review Series (V. J. May and J.D. Hansom, eds.), Peterborough: No. 28, Joint Nature Conservation Committee. <http://jncc.defra.gov.uk/pdf/gcrdb/GCRsiteaccount1067.pdf>
- Hardy, K. 2013. The Shell Middens of Scotland's Inner Hebrides. In *Shell Energy: Mollusc Shells as Coastal Resources* (G. N. Bailey, K. Hardy & A. Camara, eds.): 123–136. Oxford: Oxbow Books.
- Hardy, K. 2016. Variable Use of Coastal Resources in Prehistoric and Historic Periods in Western Scotland. *The Journal of Island and Coastal Archaeology* 11(2): 264–284.
- Hardy, K., Camara, A., Piqué, R., Dioh, E., Guéye, M., Diaw Diadhiou, H., Faye, M., and Carré, M. 2016. Shellfishing and shell midden construction in the Saloum Delta, Senegal. *Journal of Anthropological Archaeology* 41: 19-32.
- Hardy, K. and C. Wickham-Jones. 2009. Introduction. In *Mesolithic and later sites around the Inner Sound, Scotland's: the work of the Scotlands First Settlers project 1998-2004* (K. Hardy & C. Wickham-Jones, eds.) *Scottish Archaeology Internet Report* 31: 37–47.
- Harland, J. & Barrett, J.H. 2012. The maritime economy: fish bone. In *Being an Islander: Production and Identity at Quoygreew, Orkney, AD 900-1600* (J. Barrett, ed): 115-138. Cambridge: McDonald Institute.
- Hawke-Smith, C. F. 1980. Two Mesolithic Sites near Newburgh, Aberdeenshire. *Proceedings of the Society of Antiquaries of Scotland* 110: 497–520.
- Hedges, J. W. 1983. Trial excavations on Pictish and Viking settlements at Saevar Howe, Birsay, Orkney. *Glasgow Archaeological Journal* 10: 73–124.

- Horsey, I. P. & J. M. Winder. 1992. The Late Saxon and Conquest Period Oyster Middens. In *Excavations in Poole 1973-1983* (K. S. Jarvis, ed.): 60–6. Dorset Natural History and Archaeological Society Monograph Series Number 10.
- Jamieson, T. 1865. On Some Remains of the Stone Period in the Buchan district of Aberdeenshire. *Proceedings of the Society of Antiquaries of Scotland* 6: 240–245.
- Kirk, W. 1954. Sands of Forvie. *Discovery and Excavation Scotland* 1954: 5–6.
- Kirk, W. 1955. Sands of Forvie. *Discovery and Excavation Scotland* 1955: 3–4.
- Mallory, J.P. and P. C. Woodman. 1984. Oughtymore: an early Christian shell midden. *Ulster Journal of Archaeology* 47: 51–62.
- Mannino, M. A. and Thomas, K. D. 2001. Intensive Mesolithic exploitation of coastal resources? Evidence from a shell deposit on the Isle of Portland (Southern England) for the impact of human foraging on populations of intertidal rocky shore molluscs. *Journal of Archaeological Science* 28 (10): 1101–1114.
- Mays, S. & N. Beavan. 2012. An investigation of diet in early Anglo-Saxon England using carbon and nitrogen stable isotope analysis of human bone collagen. *Journal of Archaeological Science* 39: 867–874.
- Mellars, P.A., 1987. *Excavations on Oronsay. Prehistoric Human Ecology on a Small Island*. Edinburgh: Edinburgh University Press.
- Milner, N., Barrett, J. and Welsh, J. 2007. Marine resource intensification in Viking Age Europe: the molluscan evidence from Quoygrew, Orkney. *Journal of Archaeological Science* 34: 1461–1472.
- Milner, N. and Barret, J. 2012. The Marine Economy: Mollusc Shell. In *Being an Islander: Production and Identity at Quoygrew, Orkney, AD 900-1600* (J. Barrett, ed.): 103–113. Cambridge: McDonald Institute Monographs.
- Milner, N., Craig, O. E. and G. N. Bailey, eds. 2007. *Shell Middens in Atlantic Europe*. Oxford: Oxbow Books.
- Milner, N., Craig, O. E. & G. N. Bailey. 2007. Shell Middens in Atlantic Europe. In Milner et al. 2007: 1–4.
- Milner, N. & P. Woodman. 2007. Deconstructing the myth of Irish shell middens. In Milner et al 2007: 101–110.

- Murray, E. 2007. Molluscs and Middens: The Archaeology of 'Ireland's Early Savage Race'? In *Environmental Archaeology in Ireland* (E.M. Murphy and N.J. Whitehouse, eds.): 119–135. Oxford: Oxbow Books.
- Murray, E. & F. McCormick. 2012. Doonloughan: a seasonal settlement site on the Connemara coast. *Proceedings of the Royal Irish Academy* 112(C): 95–146.
- Noble, G., Turner, J., Hamilton, D., Hastie, L., Knecht, R., Stirling, L., Sveinbjarnarson, O., Upex, B. and Milek, K. in press. Early Medieval Shellfish Gathering at the Sands of Forvie, Aberdeenshire: the results of fieldwork 2011-16. *Proceedings of the Society of Antiquaries of Scotland* 147.
- North, S. 1981. *The sands of Forvie and Ythan Estuary National Nature Reserve: a description*. Nature Conservancy Council (North-East Scotland Region).
- O'Dell, A. C. 1960 Ardlethen Farm, Ellon. *Discovery and Excavation in Scotland* 1960: 2.
- O'Sullivan, A., McCormick, F., Kerr, T. R. & L. Harney. *Early Medieval Ireland AD 400–1100: The Evidence from Archaeological Excavations*. Dublin: Royal Irish Academy Monographs.
- Parmalee, P. W., and Klippel, W.E. 1974. Freshwater Mussels as a Prehistoric Food Resource. *American Antiquity* 39(3): 421–434.
- Rackham, D. J. 1989. Marine Shellfish. In *The Birsay Bay Project Volume 1. Coastal Sites beside the Bough Road, Birsay, Orkney. Excavations 1876-1982* (C. D. Morris, ed.): 259–262. Durham: University of Durham Department of Archaeology Monograph Series number 1.
- Ralston, I. 1997. The archaeology of the Sands of Forvie and the Ythan valley. In *The Ythan: Festschrift for Professor George M. Dunnet* (M. L. Gorman, ed.): 20–37. Aberdeen: University Department of Zoology.
- Ralston, I., Sabine, K. A. and contributions by Boardman, S. J., Edwards, K. J., Gemmell, A. M. D., Greig, M. K., McKinley, J. I. and Sabine, P. A. 2001. *Excavations of Second and First Millennia BC remains on the Sands of Forvie, Slains, Aberdeenshire. O'Dell Memorial Monograph 28*. Aberdeen: Dept of Geography and Environment, University of Aberdeen.
- Reimer, P., Bard, E., Bayliss, A., Beck, J., Blackwell, P., Bronk Ramsey, C., Buck, C., Cheng, H., Edwards, R., Friedrich, M., Grootes, P., Guilderson, T., Hafliðason, H., Hajdas, I., Hatté, C., Heaton, T., Hoffmann, D., Hogg, A., Hughen, K., Kaiser, K., Kromer, B., Manning, S., Niu, M., Reimer, R., Richards,

- D., Scott, E., Southon, J., Staff, R., Turney, C., Van Der Plicht, J. 2013. IntCal13 and Marine13 Radiocarbon Age Calibration Curves 0–50,000 Years cal BP. *Radiocarbon* 55: 1869–1887.
- Richards, M.P., Schulting, R.J. and R.E.M. Hedges. 2003. Sharp shift in diet at onset of Neolithic. *Nature* 425: 1.
- Rippon, S. 2000. Exploitation and Modification. Changing Patterns in the use of Coastal Resources in Southern Britain during the Roman and Medieval periods. In *The Rising Tide. Archaeology and Coastal Landscapes* (A. Aberg and C. Lewis, eds.): 65–74. Oxford, Oxbow Books.
- Rippon, S. 2010: Landscape change in the “Long Eighth Century”. In *The Landscape Archaeology of Anglo-Saxon England* (N. Higham and M.J. Ryan, eds.): 39–64. Woodbridge: Boydell.
- Ritchie, Anna. 1977. Excavation of Pictish and Viking-age farmsteads at Buckquoy, Orkney. *Proceedings of the Society of Antiquaries of Scotland* 108: 174–227.
- Ritchie, W. 1983. Sands of Forvie. In *Northeast Scotland coastal field guide and geographical essays* (W. Ritchie, ed.): 12–19. Aberdeen: Department of Geography, University of Aberdeen.
- Ritchie, W. 1997. The Geomorphology of the Sands of Forvie. In *The Ythan, A Festschrift for George Dunnet* (M.L. Gorman, ed.): 6–18. Aberdeen: Department of Zoology, University of Aberdeen.
- Rust, J. 1845 Parish of Slains. *The New Statistical Account of Scotland 1834-45*: 589–598.
- Saville, A. 2004 Macharmuir (Logie Buchan parish), Mesolithic flints. *Discovery and Excavation in Scotland* 5: 17.
- Scotland’s National Heritage. 2009. Scottish National Nature Reserves. Forvie – Setting the Scene <http://www.nnr-scotland.org.uk/forvie/nature-and-culture/setting-the-scene/>
- Sharples, N. 2005. *Norse Farmstead in the Outer Hebrides: Excavations at Mound 3, Bornais, South Uist*. Oxford: Oxbow Books.
- Sharples, N. 2005a. Comparative analysis of floors and middens: Marine shell. In Sharples 2005: 146–147.
- Sharples, N. 2005b. Resource exploitation: The Shore. 1. Shellfish. In Sharples 2005: 159–161.
- Sharples, N. (ed.) 2012. *A Late Iron Age Farmstead in the Outer Hebrides: Excavations at Mound 1, Bornais, South Uist*. Oxford: Oxbow Books.
- Sharples, N. 2012. Resource exploitation: The Shore 1. Shellfish. In Sharples (ed.) 2012: 228.
- Sharples, N. & Light, J. 2012. Comparative analysis of the site assemblage: Marine shell and crab. In Sharples (ed.), 2012: 201–203.

- Shepherd, I. 1983 Foveran Links, flint working site. *Discovery and Excavation in Scotland* 1983: 11.
- Simpson, I. A., Barrett, J. H. and Milek, K. B. 2005. Interpreting the Viking Age to Medieval Period transition in Norse Orkney through cultural soil and sediment analysis. *Geoarchaeology* 20(4): 355–377.
- Sloan, D. 1982. Nether Kinneil. *Current Archaeology* 84: 13–15.
- Smith, D. E., Cullingfor, R. A. and Brooks, C. L. 1983. Flandrian relative sea level changes in the Ythan valley, NE Scotland. *Earth Surface Processes and Landforms* 8: 423-438.
- Sneddon, J., and I. Ralston 1984. Mains of Waterton (Ellon parish), Flint artefacts. *Discovery and Excavation in Scotland* 1984: 11.
- Sneddon, J., and I. Shepherd 1985. Mains of Waterton (Ellon parish), Mesolithic rockshelter, possible. *Discovery and Excavation in Scotland* 1985: 17.
- Sneddon and Shepherd, D. J. and I. A. G. 1985. Mains of Waterton (Ellon parish): mesolithic rockshelter, possible. *Discovery and Excavation Scotland* 1985: 17
- Szabo, K. Prehistoric Shellfish Gathering http://www.manandmollusc.net/history_food.html
- Thoms, A. V. 2009. Rocks of ages: propagation of hot-rock cookery in western North America. *Journal of Archaeological Science* 36: 573–591.
- Tipping, R. 2007. Environmental History. In: RCAHMS, *In the Shadow of Bennachie; a field archaeology of Donside, Aberdeenshire*: 25–44. Edinburgh: RCAHMS.
- Verhaeghe, F. 2005. Urban developments in the age of Charlemagne. In *Charlemagne: Empire and Society* (J. Story, ed.): 259–287. Manchester: Manchester University Press.
- Ward, G.K. and Wilson, S.R. 1978. Procedures for comparing and combining radiocarbon age determinations: a critique. *Archaeometry* 20: 19–32.
- Warren, G. 1999 Sands of Forvie (Slains parish), Mesolithic lithic scatters and middens. *Discovery and Excavation in Scotland* 1999: 10–11.
- Warren, G. 2005 Recent fieldwork at the Sands of Forvie, Aberdeenshire. Unpublished report: University of Dublin.
- Waselkov, G. A. 1987. Shellfish Gathering and Shell Midden Archaeology. *Advances in Archaeological Method and Theory* 10: 92–210.

Wheeler, A. 1977. The fish bones from Buckquoy, Orkney. In *Excavation of Pictish and Viking-Age farmsteads at Buckquoy, Orkney* (A. Ritchie, ed.). *Proceedings of the Society of Antiquaries of Scotland* 108: 211–214.

Wickham-Jones, C. 2007. Middens in Scottish prehistory: time, space and relativity. In Milner et al. 2007: 86–93.

Willemsen, A. and H. Kik, eds. 2010. *Dorestad in an International Framework: New Research on Centres of Trade and Coinage in Carolingian Times*. Turnhout: Brepols.

Woodman, P. 2013. Shell Energy: An Overview. In *Shell Energy: Mollusc Shells as Coastal Resources* (. N. Bailey, K. Hardy & A. Camara, eds.): 299–307. Oxford: Oxbow Books.

Woolf, A. 2007. *From Pictland to Alba, 789–1070*. Edinburgh: Edinburgh University Press.