The Oxford Handbook of Neolithic Europe
eds. C. Fowley, J. Harding and D. Hofmann Oxford University Press

Subsistence practices in western and northern Europe

P.A. Rowley-Conwy and A.J. Legge

KEY WORDS

Neolithic, cultivation, agriculture, domestic animals, crops, Northwest Europe, Linearbandkeramik (LBK), Southern Scandinavia, Britain

ABSTRACT

Early agriculture in Northwest Europe was highly diverse. Sometimes it spread rapidly, at other times it scarcely advanced at all, and in Southern Scandinavia it retreated after its initial advance. Linearbandkeramik (LBK) farmers occupied small clearings on loess soils, concentrating on cattle and cereals and hardly exploiting the surrounding forest at all. After more than a millennium agriculture spread into Southern Scandinavia; after an initial period in which some settlements contained many wild animals, by the Middle Neolithic agriculture was ubiquitous. It did not spread into southern Norway until the Late Neolithic, and in the badlands between the loess soils of central Europe and the glacial moraine of Southern Scandinavia hunting remained important throughout the Neolithic. In Britain, most regions saw cultivation and domestic animals rapidly come to predominate the economy, but northwestern Scotland may have continued hunting, fishing, and gathering until later in the Neolithic.

INTRODUCTION

This chapter considers domestic animals and plants in the Neolithic of western and northern Europe. Perhaps no other region on the planet has seen research as intensive and as long-term, but despite this the nature and significance of early agriculture is still keenly debated. There is little agreement even on many of the basic issues: how rapidly was agriculture established as the dominant way of life in the various parts of the region? In what proportions did immigrant farmers and indigenous foragers contribute their genes to Europe's later population? Were any of the major plants or animals locally domesticated? Our information often remains patchy and sometimes contradictory, but current work is transforming our understanding of these issues.

We start with the northern and western parts of the Linearbandkeramik (LBK). This farming culture originated in the Hungarian Plain c. 5700 cal BC, and spread west to the Paris Basin in a couple of centuries (Schier this volume). This parallels the very rapid near-contemporary Cardial farming spread round the central and western Mediterranean coasts (Bogaard and Halstead this volume). West of the Alps, the two axes slowed and converged, and farming reached the Biscayan coast of France by c. 5000 cal BC. To the north of the LBK, the spread of farming stopped for 1500 years, after which it again spread remarkably rapidly at c. 4000 cal BC, reaching Ireland, Scotland, and Scandinavia as far north as Oslo and Stockholm.

ENERGETICS

Hunter-gatherers are often (but not always) mobile, exploiting seasonal resources in different places. Large-scale food storage is rare. Farming systems imposed quite different needs. Neolithic farmers made their living mainly from their domestic animals and plants, and these involved much smaller areas of land. Cereals were grown in small fields cleared of vegetation, no doubt initially assisted by rooting domestic pigs. The domestic animals were closely managed. Food storage was the key to the growth and dispersal of the Neolithic way of life. The farmers would have stored substantial amounts of cereals and processed milk products. This imposed a largely sedentary life, with people tied to their fields and food stores. Farming thus brought about profound social change.

Neolithic farming could extract much more energy from a given area than foraging. Hunter-gatherers usually gain about 10-15 times more food energy than they expend obtaining it. Traditional farmers do better, gaining 20-40 times the energy they expend (Leach 1976). One Neolithic family could satisfy their food needs from the cultivation of just a couple of hectares. A hypothetical farming village of 100 people would utilize perhaps 150-200 hectares, though grazing would use additional land. The population density of farmers on suitable land would clearly be very much higher than that of hunter-gatherers.

Farming thus brought about a profound change in population density. Most hunter-gatherers have low population densities, due to the constraints of lean seasons (Rowley-Conwy and Layton 2011). The situation has been quite different in farming societies. Sedentary groups can wean children much earlier, because stored cereals and milk products provide ideal weaning foods; in consequence each woman could have multiple births. The parish records of British villages reveal that only a century or two ago families of 10, 12, or even more children were quite common. Once farming was firmly established, there was no return to earlier ways.

METHODS AND INTERPRETATIONS

Neolithic agriculture is studied through the remains of the animals and plants themselves. Preservation and recovery of these is problematic: animal bones often preserve fairly well unless soil conditions are too acidic, while plant tissues normally decay rapidly. On most European farming settlements we only see plant remains that have been exposed to fire and which survive by charring, a taphonomic window that it is vital we bear in mind.

The differential size of bone fragments means that excavated samples may be biased: excavators using trowels will find most cattle bones, but fewer sheep and even fewer chicken bones. A sieving regime is thus a vital ingredient of any excavation strategy (Legge and Hacker 2010). This should include sub-sampling with a smaller mesh to find very small bones; only a 1 mm sieve mesh will recover small fish such as herring in the proper proportion (Enghoff 2011, table 41).

Charred plant remains are more difficult to recover systematically. A burnt cereal store is usually visible during excavation, but lower-density samples such as those in middens or back-filled pits are not. Hazel nut shell fragments are more visible than cereal grains. Such factors are clearly likely to lead to bias. A systematic approach to recovery by flotation is therefore essential, preferably done on a large scale during the excavation itself. Various kinds of recovery unit are employed (Jarman *et al.* 1972). A consistent regime such as sampling 10% of all contexts should be the norm (van der Veen and Fieller 1982).

Even optimally recovered samples must be interpreted – these data do not 'speak for themselves'. We must always remember that Neolithic farmers did not deliberately create an archaeological record for our benefit. The animal bones are the discarded waste products from successful human utilization of animal products. Plant remains may survive accidentally – the accidental burning of a cereal store – or incidentally – the discard of waste products (weeds, chaff, nutshell) into a fire. Samples of 1000 animal bones, and 1000 charred plant fragments, tell very different kinds of story: the animal bones probably accumulated over a period of time, as individual animals were slaughtered and consumed, while the plant fragments may have been burnt in an episode taking only moments. The animal bones from a site therefore present an averaged picture of the economy, while numerous plant samples from the same site each present a snapshot of economic activity.

The way this affects interpretation is shown by the British Neolithic samples in Figure 1. The animal assemblages are remarkably consistent, suggesting that the animal economy was cattle-based in southern England at least. The predominance of pig on late Neolithic sites is a major change resulting from a different mode of animal consumption (Serjeantson 2011, Rowley-Conwy and Owen 2011). The plant remains are however much more variable. The late Neolithic samples from Scord of Brouster comprise a 'house floor' sample, almost entirely edible barley, perhaps an accident during food preparation, and a 'hearth' sample, predominantly inedible weeds and chaff. Cereals need processing to separate them from these waste products (Hillman 1981). The final fine sieving removes small weed seeds and chaff fragments. The 'hearth' sample is probably this kind of waste, disposed of into the fire by which the barley processor sat.

Wild pigs and cattle were present in Neolithic Europe, and separating wild from domestic can be problematic. In both species, wild were larger than domestic, but sexual dimporphism in cattle means that Neolithic wild females about the same size as domestic males, which can pose a challenge. Pigs are not sexually dimorphic but have other problems: they are often supposed to have been loosely herded by Neolithic farmers, so bones of feral and mixed specimens may occur. The size range in a single population is however quite well understood (Albarella and Payne 2005), and a recent survey has shown that most European Neolithic pigs were in fact close-herded and fully domestic (Rowley-Conwy *et al.* 2012).

Dairy products were important. Before Neolithic times, humans would seldom consume milk after weaning. To digest milk, young mammals produce the digestive enzyme lactase until they are weaned. Some humans however continue to produce lactase into adult life, particularly in northern Europe, which allows them to consume milk throughout their lives. Some zooarchaeologists have argued that this was post-

Neolithic adaptation. However, the gene for continued lactase production occurs in Neolithic humans from Sweden (Malmström *et al.* 2008), and lipids from milk have been found in Neolithic pottery (Evershed *et al.* 2008). The cattle bones themselves have long been argued to show dairying (Legge 1981). The clearest zooarchaeological example is the Bronze Age site of Grimes Graves (Fig. 2). In dairy herds, most male cattle are killed shortly after birth, to free the milk for human use. The adult herd thus consists largely of the breeding and lactating females. At Grimes Graves many animals were killed very young, seen in the steep reduction in 'percent survival' next to the vertical axis in Figure 2A. Jaws cannot be sexed, so sex ratios among older animals are established through limb bones. Distal humerus and distal metacarpal, which fuse at 12-18 months and 24-30 months respectively, show that by these ages the herd already consisted mainly of females (Fig. 2B-C). The high kill in the first couple of months (Fig. 2A) must therefore comprise the missing males.

THE NORTHERN AND WESTERN LBK

The rapidity of the LBK spread across the loess soils of Central Europe is no longer put down to shifting cultivation. European soils do not lose their fertility after a couple of years, so there would be no need to move to a new location (Lüning 1980; Rowley-Conwy 1981). LBK people lived in permanent and quite widely dispersed settlements. Thick forest faced the colonists, inhibiting their ventures, so the LBK may have spread by boat, along the major rivers where the earliest settlements are found (Rowley-Conwy 2011). There would have been few natural clearings, although some areas along watercourses may have been clear of forest (Kreuz 2008).

Although LBK settlements were surrounded by forest, farmers made remarkably little use of its products. The animal bones are dominated by domestic animals. Figure 3 presents three examples spanning the LBK's northern edge from Paris to Poland. Cattle predominate, because they cope relatively well with forest grazing. This was a new development in the European Neolithic: farmers to the southeast relied on sheep and goats as their main domesticate. LBK farmers reconfigured the animal economy for the central European forest environment. Pigs were also suited to this forest, but they were not common, often being outnumbered by sheep. This suggests that the animal economy was centred on the farming clearings themselves: the wild and domestic pigs remained of different sizes, suggesting there was little interbreeding between the two. Domestic pigs were evidently close-herded near the settlements (Rowley-Conwy *et al.* 2012).

LBK farmers arrived with the full suite of domestic animals. Cattle were not independently domesticated in central Europe, and their DNA shows that the breed had its origins in modern Anatolia (Legge 2010). Figure 4 presents distal metacarpal measurements from various populations. The Danish sample of aurochs forms the metrical benchmark. The German LBK animals are considerably smaller, and at no sites are there animals intermediate in size between aurochs and domestic cattle. Pigs are more complex. The first domestic animals in Europe carried Near Eastern mtDNA, indicating importation from that region. Later in the LBK, morphologically domestic pigs appear that carried the mtDNA lineage of European wild boar. This suggests that farmers incorporated female wild boar into their domestic pig population

(Larson *et al.* 2007). There is zooarchaeological evidence that this happened in the Paris Basin (Tresset and Vigne 2007, fig. 2).

Cultivation was also modified to suit the temperate forest environment. The wide range of crops cultivated in the Balkan Neolithic dwindled to just five: einkorn wheat, emmer wheat, pea, lentil, and linseed (Kreuz 2007). It is remarkable that barley, now tolerant of poorer conditions than the wheat species, was not part of this crop suite. Two botanical assemblages are shown in Figure 3. As discussed above, these fully agricultural economies are represented mainly by their waste products: chaff and weed seeds. The weed seeds are characteristic of crops grown in small intensively-cultivated 'garden' plots rather than more extensive fields (Bogaard 2004), so cultivation was probably carried out with hoe and digging stick rather than the ard. The pig may also have been useful as a quasi-tool, preparing and manuring land in advance of sowing (Rowley-Conwy 1981). It is not clear whether the sowing season continued to be the autumn, as in the Balkans (Bogaard 2004), or was changed to the spring (Kreuz and Schäfer 2011)

The LBK thus appears as a scatter of specialist 'loess farming units', operating a system of agriculture that was considerably modified from that of its parent cultures in the Balkans. It is remarkable how little attention the LBK farmers paid to the resources of the forests that surrounded them: their economic efforts were focussed almost entirely on farming the clearings they occupied.

NEOLITHIC FARMING NORTH OF THE LBK

Along its northern border, the LBK spread stopped as abruptly as it had begun. It had reached the northern edge of the loess to which it was adapted. Well drained and fertile morainic soils lay further north in southern Scandinavia, but the loess was separated from this by a zone of poor glacial outwash sands, which formed a zone of 'badlands' not well suited to agriculture.

The farming standstill lasted for some 1500 years. Mesolithic hunter-gatherer populations were extensive well to the north – the Ertebølle of southern Scandinavia – and also closer to the farmers further west – the Swifterbant of the Rhine-Waal-Maas estuarine complex and the Ijsselmeer. Fewer appear to have occupied the area between the LBK and the Ertebølle. Whether these hunter-gatherers acquired any domestic animals from the farmers has been a subject for discussion for several decades.

Some specific instances of claimed domestic animals may be mentioned. A *Bos* metacarpal from Rosenhof in northern Germany was originally claimed to be domestic (Nobis 1975), although there were grounds for believing it was from an aurochs (Rowley-Conwy 2003). Recently, molecular biological work has suggested that the animal was indeed wild: its diet was similar to aurochs (Noe-Nygaard *et al.* 2005), and its mtDNA lineage was of Near Eastern not native European origin (Scheu *et al.* 2008). Some other cases are claimed, including a few goat bones in the Netherlands (reviewed in Rowley-Conwy 2013). The goats are undated by radiocarbon, but if they really are Mesolithic they must have been acquired from, or have escaped from, the nearby farmers.

Farming finally spread northwards around 4000 cal BC. The *Trichterbecher* or *trægtbæger* (TRB) extended north to the latitude of Oslo and Stockholm. Its farming regime was very different from that of the LBK (Fig. 5). The cultivation regime was further modified: peas and lentils, fairly common in the LBK, disappear; einkorn diminishes nearly to vanishing point; and barley reappears and dominates at some sites. In the late Neolithic, cereal agriculture spread into southwestern Norway, and the sample from Voll has mostly barley among the identified cereal grains (Fig. 5). In Denmark, the ard was present at Hanstedgård at the start of the middle Neolithic around 3300 cal BC (Eriksen and Madsen 1984), and at the late Neolithic site of Hjelle in southwestern Norway, at the time of the first evidence for cultivation in this region (Soltvedt 2000).

The animal economy was also different: the LBK uniformity disappeared. Some sites have a dominance of domestic animals (Fig. 5), and even at Skumparberget, at the northern extremity of the TRB near Stockholm, the bones comprised only domestic animals with cattle at 82% (Bäckström 1996). But at other sites wild mammals predominate. In Denmark, Muldbjerg I and others have a large proportion of wild mammals in the early Neolithic, before c. 3300 cal BC. Thereafter domestic species predominate everywhere. Isotopes in human bone mostly suggest a terrestrial diet, based presumably on agriculture, from the start of the Neolithic (Richards and Koch 2001). Further south, in northern Germany, wild resources continued to be significant until much later. Hüde I (TRB layer) is dominated by wild mammals (Fig. 5), and Parchim continues this pattern into the late Neolithic. Some of the sites in this region have remarkably high frequencies of wild horse (Sommer *et al.* 2011), and many also have substantial numbers of beaver and otter, birds, and fish (reviewed in Rowley-Conwy 2013). All in all the evidence for agriculture in the ‘no man’s land’ region between the northern edge of the former LBK area and the Baltic hinterland is rather weak throughout the Neolithic.

At the end of the early Neolithic around 3300 BC, agriculture went into retreat: the northern edge of farming withdrew from near Stockholm and the island og Gotland, to the southernmost part of Sweden in the middle Neolithic. So-called ‘Pitted Ware’ hunter-fishers replaced TRB farmers in much of the central Baltic. Ancient DNA suggests that Pitted Ware people may have been of a different ethnicity to the farmers (Malmström *et al.* 2009). On Gotland, wild boar replaced the domestic animals of earlier times (Rowley-Conwy *et al.* 2012). Animal bones from Pitted Ware sites are overwhelmingly from wild animals (reviewed in Rowley-Conwy 2013), and stable isotopes in human bones reveal that Pitted Ware people throughout eastern Sweden consumed a diet very high in marine foods (Fornander *et al.* 2008).

BRITAIN AND IRELAND

The earliest sign of any domestic species in this region (apart from the dog) is from Ferriter’s Cove in southwestern Ireland. Two domestic cattle bones have been directly dated to c. 4300 cal BC (Woodman *et al.* 1999). How they arrived there is unclear (Tresset this volume); no continental Neolithic influence can be seen on Britain at this time, which remained firmly Mesolithic, so direct contact with possible areas of origin such as Brittany is most likely. Perhaps the bones arrived in joints of meat rather than live animals.

The Neolithic appears in Britain just before 4000 cal BC, in Ireland perhaps a century or two later (Whittle *et al.* 2011). The British Neolithic is the scene of a unique debate about the onset of farming: was the adoption gradual, with a mobile 'Mesolithic' lifestyle continuing through much of the period (e.g., Thomas 2008), or rapid, involving a considerable amount of immigration (e.g., Rowley-Conwy 2004)? Or is a middle position, stressing local variability, the best option (e.g., Cummings and Harris 2011)?

Animal bones from almost all Neolithic sites have an overwhelming predominance of domestic animals (see Fig. 1). There is now general agreement that aurochs, wild boar, and deer are surprisingly rare (Legge 2010; Serjeantson 2011). The only exception is the isolated early Neolithic pit at Coneybury (the 'Coneybury anomaly'), which contains the remains of 10 domestic cattle and 7 roe deer, perhaps the remains of a single feasting event (Maltby 1990). This is the only site of this kind, and the roe deer in any case produce less than 10% of the meat weight (Rowley-Conwy 2003b, fig. 5). It would certainly not be safe to generalize from it to the whole Neolithic economy. It is true that animal bone assemblages from the first couple of centuries of the Neolithic remain elusive, and those plotted in Figure 1 are from ritual monuments. Assemblages from settlements, dated to the crucial couple of centuries, will be of the greatest interest. What can be said at this stage is that by the time the early Neolithic was fully established, wild species played only a peripheral role in the economy.

Apart from some fines of linseed, cultivated plants are dominated by just two species, emmer and barley, with bread wheat appearing at a few sites; barley apparently becomes more common in the later Neolithic. The importance or otherwise of the cereals has been very contentious. We saw in the methodology section that we cannot simply sum the plant remains from any site and expect that the result will present an 'averaged' picture of the economy in the way that the animal bones do. The contrasting samples from Scord of Brouster make this clear (Fig. 1). Workers elsewhere in Europe all assume that cultivated cereals were overwhelmingly predominant despite the high frequency of weeds at some sites (e.g., Bedburg-Garsdorf in Fig. 3). Hazel nut shell is common at many British Neolithic sites. Samples containing many weeds and hazel nut shells, interpreted at face value, have been used to suggest that wild species provided most of the plant food (e.g., Thomas 2003). But nut shell, like weed seeds, is a waste product, which may even have been used for kindling and thus commonly be charred (Jones 2000). Recognition of the complexities of plant samples suggests that cereals were predominant in most places: what we see are their waste products, discarded as useless and burnt by chance along with the nut shell (e.g., Legge 1989; Jones and Rowley-Conwy 2007).

The problems are illustrated by the samples in Figure 1, all from early Neolithic timber houses. Tankardstown in Ireland is dominated by cereals, with an admixture of apple or pear; chaff and weeds are uncommon. Chaff is much more common at Lismore Fields 1; while at Yarnton hazel nut shell predominates. The early Neolithic plant economy was however probably fairly similar at all three: the chance exigencies of charring caution us not to accept these samples at face value. This understanding has led to a recent reappraisal of the role of cereals in the British Neolithic: even the proponents of a gradual transition and the continuation of a largely 'Mesolithic' economy into the artefactual Neolithic now restrict their arguments to the *early* Neolithic (Thomas 2008). A degree of regional variation (Cummings and Harris 2011) remains possible: Bishop *et al.* (2010) found that while agricultural plants dominated the Neolithic economy in most of Scotland, the Outer Hebrides might have persisted in a largely hunter-gatherer way of life. The importance of cereals in the earlier Neolithic is now generally accepted, to the extent that a cereal decline has recently been suggested for the later Neolithic (Stevens and Fuller 2012); but whether this is anything other than an artefact of research emphasis remains to be seen.

The importance of dairying has been mentioned. We lack settlement sites producing samples like that from Grimes Graves (Fig. 2). Most information on the Neolithic economy in England comes from sites of a ceremonial or ritual nature, such as the causewayed enclosures (Andersen this volume). Distal metacarpal measurements from three are plotted in Figure 4. The British sites, like contemporary Troldebjerg in Denmark, have smaller cattle than the German LBK sites, reflecting the fact that they are some 1500 years younger. Unlike Troldebjerg, however, cattle ate the British sites doe not diviede equally between the sexes: females predominate at all three.

Cattle at Hambledon Hill cattle were killed mostly between 2 and 4 years of age (Legge 2008). An economy in which dairy husbandry was highly developed would have a surplus of young females at precisely this age, when the best breeding cows would be selected while those with less desirable traits would be culled and eaten. Further, the cattle bones at Hambledon Hill showed less breakage than is commonly found at archaeological sites, often with the limb segments discarded with the bones still in articulation. This shows that the cattle were consumed in a more lavish manner than usual, indicative of large-scale meat consumption in the manner of feasting. The cereals too were brought partly prepared. Hence, this was a site for consumption rather than a place where such foods were raised and prepared. Thus while the entire cattle economy is not represented ere i the way that it is at Grimes Graves, the pattern nevertheless supports the argument for a dairy economy.

CONCLUSIONS

We have traced the arrival and development of farming in the Neolithic of western and northern Europe. The spread was not steady; it stopped at the northern edge of the LBK for some 1500 years before it then rapidly moved into southern Scandinavia, Britain, and Ireland; northern central Germany was apparently missed out of the initial advance, being infilled only later; and the spread into environmentally hostile regions such as northwestern Scotland was delayed.

For the most part, however, the spread of agriculture appears to have been a rapid and complete process. Claims for domestic animals (other than the dog) in Mesolithic contexts have almost all proved spurious – Ferriter's Cove in Ireland is an outstanding exception to this. The 'Mesolithic' economic component in most Neolithic economies is currently being downplayed. Consequently most transition events look much sharper than they did just a few years ago (Rowley-Conwy 2011).

A gradual transition implies local continuity, and thus a considerable local component in the human population that became farmers – though some immigrants are never excluded. A rapid transition need not imply local community, but could be brought about by immigrant farmers – though of course some local involvement is never excluded either. This debate continues. As the study of prehistoric genetics becomes more routine, more light will be cast on this issue. But for the time being the pendulum has swung towards a greater immigrant component. Whether this will stand the test of time will be a matter of great future interest.

SHORT BIOGRAPHIES

Peter Rowley-Conwy is Professor of Environmental Archaeology at Durham University. He has examined assemblages of early agricultural animal bones and plant remains in a variety of places including Denmark and Sweden, Italy, Portugal, Russia, Syria, and Egypt. He specialises on the identification of wild and domestic pigs, and ran the 'Durham Pig Project' in the early 2000s. He has written extensively on the domestication of pigs and other animals and the spread of farming across Europe.

Tony Legge died while this chapter was in press. He developed improved methods of sieving for animal remains, and flotation for plant remains, and these have been widely adopted on archaeological excavations. He was a pioneer in the identification of domestic animals, starting with gazelle and sheep/goat in the Near East, and later turning to cattle and pigs in Europe. Over 30 years ago he was instrumental in putting forward the then-controversial suggestion that cattle were milked in the British Neolithic. He worked in Israel, Syria, Croatia, Spain, Turkmenistan and Cyprus, as well as several major sites in Britain, including Hambledon Hill.

REFERENCES

Albarella, U. and Payne, S. 2005. Neolithic pigs from Durrington Walls, Wiltshire, England: a biometrical database. *Journal of Archaeological Science* 32, 589-99 and http://ads.ahds.ac.uk/catalogue/projArch/pigs_durham_2004/.

Armour-Chelu, M. 1998. The animal bone. In F. Pryor (ed), *Etton. Excavations at a Neolithic Causewayed Enclosure near Maxey*, 49-77. London: English Heritage. (Archaeological Report 18).

Bäckström, Y. 1996. Benfynd. In J. Apel (ed), *Skumparberget 1 och 2*, 167-180. Upplands Väsby: Arkeologikonsult AB.

Bakels, C. 1978. *Four Linearbandkeramik Settlements and their Environment: a Palaeoecological Study of Sittard, Stein, Elsloo and Hienheim*. Leiden: Leiden University Press (Analecta Praehistorica Leidensia XI).

Bishop, R.R., Church, M.J. and Rowley-Conwy, P. 2010. Cereals, fruits and nuts in the Scottish Neolithic. *Proceedings of the Society of Antiquaries of Scotland* 139, 47-103.

Bogaard, A. 2004. *Neolithic Farming in Central Europe: an Archaeobotanical Study of Crop Husbandry Practices*. London: Routledge.

Cummings, V. and Harris, O. 2011. Animals, people and places: the continuity of hunting and gathering practices across the Mesolithic-Neolithic transition in Britain. *European Journal of Archaeology* 14, 361-82.

Degerbøl, M. and Fredskild, B. 1970. *The Urus (Bos primigenius Bojanus) and Neolithic Domesticated Cattle (Bos taurus domesticus Linné) in Denmark*. Copenhagen: Det Kongelige Dansk Videnskabernes Selskab (Biologiske Skrifter 17, 1).

Döhle, H.-J. 1994. *Die linienbandkeramischen Tierknochen von Eilsleben, Bördekreis*. Halle: Landesmuseum für Vorgeschichte (Veröffentlichungen des Landesamtes für Archäologische Denkmalpflege Sachsen-Anhalt 47).

Driesch, A.E. von den 1976. *A Guide to the Measurement of Animal Bones from Archaeological Sites.* Cambridge, Massachussets: Peabody Museum of Archaeology and Ethnology (Peabody Museum Bulletin 1).

During, E. 1986. *The Fauna of Alvastra. An Osteological Analysis of Animal Bones from a Neolithic Pile Dwelling*. Stockholm: University of Stockholm, Osteological Research Laboratory (Ossa 12, supplement 1).

Enghoff, I.B. 2011. *Regionality and Biotope Exploitation in Danish Ertebølle and Adjoining Periods*. Copenhagen: Det Kongelige Danske Videnskabernes Selskab (Scientia Danica Series B, Biologica I).

Eriksen, P. and Madsen, T. 1984. Hanstedgård. A settlement site from the Funnel Beaker culture. *Journal of Danish Archaeology* 3, 63-82.

Evershed, P., Payne, S., Sherratt, A.G., Copley, M.S., Coolidge, J., Urem-Kotsu, D., Kotsakis, K., Özdogan, M., Özdogan, A.E., Nieuwenhuyse, O., Akkermans, P.M.M.G., Bailey, D., Andeescu, R.-R., Campbell, S., Farid, S., Hodder, I., Yalman, N., Özbarasan, M., Biçakci, E., Garfinkel, Y., Levy, T. and Burton, M.M. 2008. Earliest date for milk use in the Near East and southeastern Europe linked to cattle herding. *Nature* 455, 528-31.

Fornander, E., Eriksson, G. and Lidén, K. 2008. Wild at heart: approaching Pitted Ware identity, economy and cosmology through stable isotopes in skeletal material from the Neolithic site Korsnäs in eastern Central Sweden. *Journal of Anthropological Archaeology* 27, 281-97.

Göransson, H. 1995. *Alvastra Pile Dwelling. Palaeoethnobotanical Studies*. Lund: University Press (Theses and Papers in Archaeology n.s. 6).

Grigson, C. 1999. The mammalian remains. In A. Whittle, J. Pollard and C. Grigson (eds), *The Harmony of Symbols. The Windmill Hill Causewayed Enclosure*, 164-252. Oxford: Oxbow.

Higham, C.F.W. and Message, M. 1968. An assessment of a society's attitude towards bovine husbandry. In D. Brothwell and E.S. Higgs (eds), *Science in Archaeology*, 315-30. London:

Thames and Hudson.

Hillman, G. 1981. Reconstructing crop husbandry practices from charred remains of crops. In R. Mercer (ed), *Farming Practice in British Prehistory*, 123-62. Edinburgh: University Press.

Hübner, K.-D., Saur, R. and Reichstein, H. 1988. Die Säugetierknochen der neolithischen Seeüfersiedlung Hüde I. In G. Jacob-Friesen and J. Howitz (eds), *Palynologische und säugetierkundliche Untersüchungen zum Siedlungsplatz Hüde I am Dümmer, Landkreis Diepholz*, 35-142. Neumünster: Kark Wachholz. (Göttinger Schriften zur Vor- und Frühgeschichte 23).

Jarman, H.N., Legge, A.J. and Charles, J.A. 1972. Retrieval of plant remains from archaeological sites by froth flotation. In E.S. Higgs (ed), *Papers in Economic Prehistory*, 39-48. Cambridge: University Press.

Jones, G. 2000. Evaluating the importance of cultivation and collecting in Neolithic Britain. In A.S. Fairbairn (ed), *Plants in Neolithic Britain and Beyond*, 79-84. Oxford: Oxbow Books (Neolithic Studies Group Seminar Paper 5).

Jones, G. and Rowley-Conwy, P. 2007. On the importance of cereal cultivation in the British Neolithic. In S. Colledge and J. Conolly (eds), *The Origins and Spread of Domestic Plants in Southwest Asia and Europe*, 391-419. Walnut Creek, California: Left Coast Press (University College London Institute of Archaeology Publications).

Knörzer, K.-H. 1974. Bandkeramische Pflanzenfunde von Bedburg-Garsdorf, Kreis Bergheim/Erft. In C. Andree, H.-E. Joachim and M. Ludwig (eds), *Beiträge zur Urgeschichte des Rheinlandes I*, 173-92. Bonn: Rheinland-Verlag (Rheinische Ausgrabungen 15).

Kreuz, A. 2007. Archaeobotanical perspectives on the beginning of agriculture north of the Alps. In S. Colledge and J. Conolly (eds), *The Origins and Spread of Domestic plants in Southwest Asia and Europe*, 259-94. Walnut Creek, California: Left Coast Press.

Kreuz, A. 2008. Closed forest or open woodland as natural vegetation in the surroundings of Linearbandkeramik settlements? *Vegetation History and Archaeobotany* 17, 51-64.

Kreuz, A. and Schäfer, E. 2011. Weed finds as indicators for the cultivation regime of the early Neolithic Bandkeramik culture? *Vegetation History and Archaeobotany* 20, 33-348.

Kroll, H. 1981. Mittelneolithisches Getreide aus Dannau. *Offa* 38, 85-90.

Kubiak-Martens, L. 2006. Botanical remains and plant food subsistence. In L.P.L. Kooijmans and P.F.B. Jongste (eds), *Schipluiden. A Neolithic Settlement on the Dutch North Sea Coast c. 3500 cal BC*, 317-38. Leiden: Leiden University (Analecta Praehistorica Leidensia 37/38).

Larson, G., Albarella, A., Dobney, K. and Rowley-Conwy, P. 2007. Current views on *Sus* phylogeography and pig domestication as seen through modern mtDNA studies. In A. Albarella, K. Dobney, A. Ervynck and P. Rowley-Conwy (eds), *Pigs and Humans. 10,000 Years of Interaction*, 30-41. Oxford: Oxford University Press.

Leach, G. 1976. *Energy and Food Production*. London: Science and Technology Press

Legge, A.J. 1981. Aspects of cattle husbandry. In *Farming Practice in British Prehistory,* ed. R. Mercer, 169-181. Edinburgh: University Press.

Legge, A.J. 1989. Milking the evidence: a reply to Entwistle and Grant. In A. Milles, D. Williams and N. Gardner (eds), *The Beginnings of Agriculture*, 217-42. Oxford: British Archaeological Reports (International Series 496).

Legge, A.J. 1992. *Excavations at Grimes Graves, Norfolk, 1972-1976, 4: Animals, Environment and the Bronze Age Economy*. London: British Museum Press.

Legge, A.J. 2008. Livestock and Neolithic society at Hambledon Hill. In R. Mercer and F. Healy (eds), *Hambledon Hill, Dorset, England. Excavation and Survey of a Neolithic Monument Complex and its surrounding landscape (vol. 2)*, 536-85. Swindon: English Heritage.

Legge, A.J. 2010. The aurochs and domestic cattle. In T. O'Connor and N. Sykes (eds), *Extinctions and Invasions. A Social History of British Fauna*, 26-35. Oxford: Windgather Press.

Legge, A.J. and Hacker, M.S. 2010. An efficient and robust sieving apparatus for archaeological work. *Journal of Field Archaeology,* 36, 310-15.

Lüning, J. 1980. Getreideanbau ohne Düngung. *Archäologisches Korrespondenzblatt* 10, 117-22.

Malmström, H., Gilbert, T.P., Thomas, M.G., Brandström, M., Storå, J., Molnar, P., Andersen, P.K., Bendixen, E., Holmlund, G., Götherström, A. and Willerslev, E. 2009. Ancient DNA reveals lack of continuity between Neolithic hunter-gatherers and contemporary Scandinavians. *Current Biology* 19, 1758-62.

Malmström, H., Linderholm, A., Dalén, L., Lidén, K., Storå, J., Molnar, P., Gilbert, T., Willerslev, E., Holmlund, G. and Götherström, A. 2008. Allele frequencies of the lactase gene in Scandinavian Neolithic populations, hunter-gatherers vs. farmers. In A. Linderholm (ed), *Migration in Prehistory. DNA and stable isotope analysis of Swedish skeletal material,* separately paginated. Stockholm: Stockholm University (Theses and Papers in Scientific Archaeology 10).

Maltby, M. 1990. Animal bones. In J. Richards (ed), *The Stonehenge Environs Project,* 57-61. London: Historic Buildings and Monuments Commission (English Heritage Archaeological Reports 16).

Milles, A. 1986. Charred remains of barley and other plants from Scord of Brouster. In A. Whittle (ed), *Scord of Brouster. An Early Agricultural Settlement on Shetland,* 119-22. Oxford: Oxford University Committee for Archaeology (Monograph 9).

Monk, M. 1988. Archaeobotanical study of samples from pipeline sites. In M. Gowan (ed), *Three Irish Gas Pipelines: New Archaeological Evidence in Munster*, 185-91. Dublin: Wordwell.

Müller, H.-H. 1964. *Die Haustiere der Mitteldeutschen Bandkeramiker*. Berlin: Akademie-Verlag (Deutsche Akademie der Wissenschaften zu Berlin, Schriften der Sektion für Vor- und Frühgeschichte 17, Naturwissenschaftliche Beiträge zur Vor- und Frühgeschichte teil 1).

Noe-Nygaard, N. 1995. *Ecological, Sedimentary, and Geochemical Evolution of the Late-glacial to Postglacial Åmose Lacustrine Basin, Denmark.* Oslo: Scandinavian University Press (Fossils and Strata 37).

Nobis, G. 1975. Zur fauna des ellerbekzeitlichen Wohnplatzes Rosenhof in Ostholstein I. *Schriften des Naturwissenschaftlichen Vereins für Schleswig-Holstein* 45: 5-30.

Noe-Nygaard, N., Price, T.D. and Hede, S.U. 2005. Diet of aurochs and early cattle in southern Scandinavia: evidence from ^{15}N and ^{13}C stable isotopes. *Journal of Archaeological Science* 32, 855-71.

Nyegaard, G. 1985. Faunalevn fra yngre stenalder på øerne syd for Fyn. In J. Skaarup (ed), *Yngre Stenalder på Øerne syd for Fyn*, 426-57. Rudkøbing: Langelands Museum.

Poplin, F. 1975. La faune danubienne d'Armeau (Yonne, France): ses donnés sur l'activité humaine. In A.T. Clason (ed), *Archaeozoological Studies*, 179-92. Amsterdam: North-Holland Publishing Co.

Richards, M.P. and Koch, E. 2001. Neolitisk kost. Analyser af kvælstof-isotopen ^{15}N i menneskeskeletter fra yngre stenalder. *Aarbøger for Nordisk Oldkyndighed og Historie* 1999, 7-17.

Robinson, D.E. 1998. Plantemakrofossiler fra Spodsbjergbopladsen. In H.H. Sørensen (ed), *Spodsbjerg - en Yngre Stenalders Boplads på Langeland*, 175-89. Rudkøbing: Langelands Museum.

Robinson, M. 2000. Further considerations of Neolithic charred cereals, fruit and nuts. In A.S. Fairbairn (ed), *Plants in Neolithic Britain and Beyond*, 85-90. Oxbow: Oxbow Books (Neolithic Studies Group Seminar Papers 5).

Rowley-Conwy, P. 1981. Slash and burn in the temperate European neolithic. In R. Mercer (ed), *Farming Practice in British Prehistory*, 85-96. Edinburgh: University Press.

Rowley-Conwy, P. 2003a. Early domestic animals in Europe: imported or locally domesticated? In A. Ammerman and P. Biagi (eds), *The Widening Harvest. The Neolithic Transition in Europe: Looking Forward, Looking Back*, 99-117. Boston: Archaeological Institute of America (Colloquia and Conference Papers 6).

Rowley-Conwy, P. 2003b. No fixed abode? Nomadism in the Northwest European neolithic. In *Stones and Bones. Formal disposal of the dead in Atlantic Europe during the Mesolithic-Neolithic interface 6000-3000 BC*, eds. G. Burenhult and S. Westergaard, 115-144. Oxford: Archaeopress. (British Archaeological Reports, International Series 1201).

Rowley-Conwy, P. 2004. How the west was lost. A reconsideration of agricultural origins in

Britain, Ireland and southern Scandinavia. *Current Anthropology* 45 supplement, S83-113.

Rowley-Conwy, P. 2011. Westward Ho! The spread of agriculture from Central Europe to the Atlantic. *Current Anthropology* 52(S4), 431-451.

Rowley-Conwy, P. 2013. North of the frontier: early domestic animals in northern Europe. In S. Colledge, J. Conolly, K. Dobney, K. Manning and S. Shennan (eds), *The Origins and Spread of Domestic Animals in Southwest Asia and Europe*. Walnut Creek, California: Left Coast Press.

Rowley-Conwy, P. and Layton, R. 2011. Foraging and farming as niche construction: stable and unstable adaptations. *Philosophical Transactions of the Royal Society* B366, 849-62.

Rowley-Conwy, P. and Owen, A.C. 2011. Grooved Ware feasting in Yorkshire: Late Neolithic animal consumption at Rudston Wold. *Oxford Journal of Archaeology* 30, 325-67.

Rowley-Conwy, P., Albarella, A. and Dobney, K. 2012. Distinguishing wild boar and domestic pigs in prehistory: a review of approaches and recent results. *Journal of World Prehistory* 25, 1-44.

Scheu, A., Hartz, S., Schmölke, U., Tresset, A., Burger, J. and Bollongino, R. 2008. Ancient DNA provides no evidence for independent domestication of cattle in Mesolithic Rosenhof, northern Germany. *Journal of Archaeological Science* 35, 1257-64.

Serjeantson, D. 2011. *Review of Animal Remains from the Neolithic and Early Bronze Age of southern Britain (4000 BC - 1500 BC)*. London: English Heritage. (Research Department Report Series 29).

Sobocinski, M., 1984. Zwierzece szczatki kostne z obiektow kultury ceramiki wstegowel rytej w Zalecinie i Zukowie, wojewodztwo Szczecinskie. *Roczniki Akademii Rolniczej w Poznaniu* 154, 87-99.

Soltvedt, E.C. 2000. Carbonised cereal from three Late Neolithic and two Early Bronze Age sites in western Norway. *Environmental Archaeology* 5, 49-62.

Sommer, R.S., Benecke, N., Lougas, L., Nelle, O. and Schmölcke, U. 2011. Holocene survival of the wild horse in Europe: a matter of open landscape? *Journal of Quaternary Science* 26, 805-12.

Stevens, C.J. and Fuller, D.Q. 2012. Did Neolithic farming fail? The case for a Bronze Age agricultural revolution in the British Isles. *Antiquity* 86, 707-722.

Thomas, J. 2003. Thoughts on the "repacked" Neolithic Revolution. *Antiquity* 77, 67-74.

Thomas, J. 2008. The Mesolithic-Neolithic transition in Britain. In J. Pollard (ed), *Prehistoric Britain,* 58-89. Oxford: Blackwell.

Tresset, A. and Vigne, J.-D. 2007. Substitution of species, techniques and symbols at the Mesolithic-Neolithic transition in western Europe. In A. Whittle and V. Cummings (eds), *Going Over: the Mesolithic-Neolithic Transition in North-West Europe*, 189-210. Oxford: Oxford University Press (Proceedings of the British Academy 144).

van der Veen, M. and Fieller, N. 1982. Sampling seeds. *Journal of Archaeological Science* 9, 287-98.

Whittle, A., Healy, F. and Bayliss, A. 2011. *Gathering Time: Dating the Early Neolithic Enclosures of southern Britain and Ireland*. Oxford: Oxbow Books.

Woodman, P.C., Anderson, E. and Finlay, N. 1999. *Excavations at Ferriter's Cove, 1983-85: Last Foragers, First Farmers in the Dingle Peninsula*. Bray: Wordwell.

Zeiler, J. 2006. Mammals. In L.P.L. Kooijmans and P.F.B. Jongste (eds), *Schipluiden: a Neolithic Settlement on the Dutch North Sea Coast c. 3500 cal BC,* 375-420. Leiden: Leiden University (Analecta Praehistorica Leidensia 37/38).

Figure 1. Economic remains from selected British Neolithic sites. Top: histogram showing relative frequency of the main food mammals at three Early Neolithic sites. Bottom: pie charts showing relative frequency of charred plant remains.

Bones: Windmill Hill calculated from Grigson (1999, tables 145.1-3), summing pre-bank and Early Neolithic contents, excluding ribs and antler. Hambledon Hill main enclosure ditch from Legge (2008, tables 8.6 and 8.7), assuming 3.3% of cattle are wild (cf 1 of the 30 metacarpals plotted in fig. 8.3) and 5.3% of pigs were wild (cf. 1 of the 19 measurements listed in tables 8.33 and 8.34). Etton summed from Armour-Chelu (1998, fiche tables 75 and 58-60). Plant remains: Scord of Brouster from Milles (1986, fiche tables 27-8); 'house floor' is total of samples 79-82, 'hearth' is total of samples 56-58), Yarnton from M. Robinson (2000, table 8.1), Lismore Fields 1 from Jones (in Jones and Rowley-Conwy 2007, table 23.1), Tankardstown from Monk (1988, 186-7).

Figure 2. Age and sex of the cattle from Grimes Graves, showing the evidence for dairy production. Top: mortality curve based on the mandibles (data from Legge 1992, table 6d). Middle and bottom: dimensions of fused distal humeri and distal metacarpals, with tentative sexual division (data from Legge 1992, appendix 1). Measurements as defined by von den Driesch (1976).

Figure 3. Economic remains from a few LBK sites. Top: histogram showing relative frequency of the main food mammals at three sites in France, Germany, and Poland. Bottom: pie charts showing relative frequency of charred plant remains.

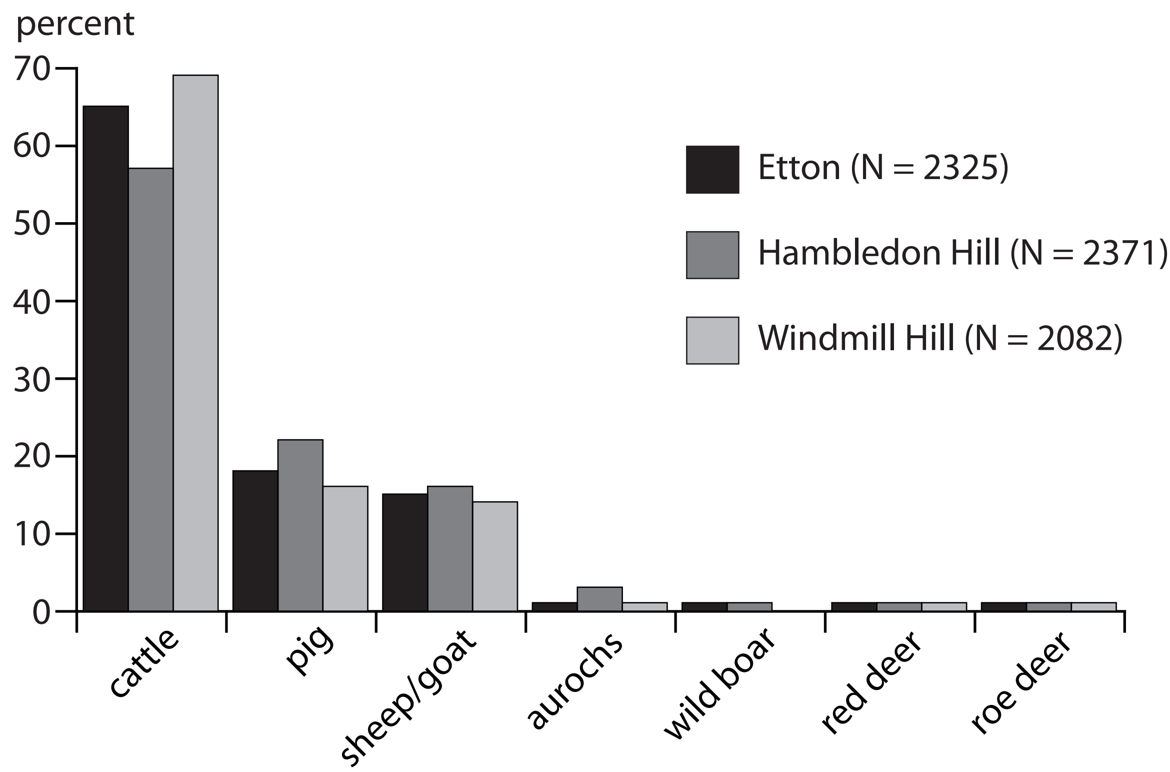
Bones: Armeau from Poplin (1975), Eilsleben from Döhle (1994, tab. 6), Zalecino from Sobocinski (1984, table 2). Plant remains: Hienheim from Bakels (1978, table 15), Bedburg-Garsdorf from Knörzer (1974, tab. 1), Oldenburg-Dannau LA191 from Kroll (1981).

Figure 4. Histograms of cattle metacarpal distal breadth, BD as defined by von den Driesch (1976). Danish aurochs from Degerbøl and Fredskild (1970, table 11), German LBK from Müller (1964, 154) and Döhle (1994, 186-187), Troldebjerg from Higham and Message (1968 table C), Etton from Armour-Chelu (1998, Appendix 1), Hambledon Hill from Legge (2008, table 8.28), Windmill Hill from Grigson (1965, table VII, xv, 1999, appendix 1.1).

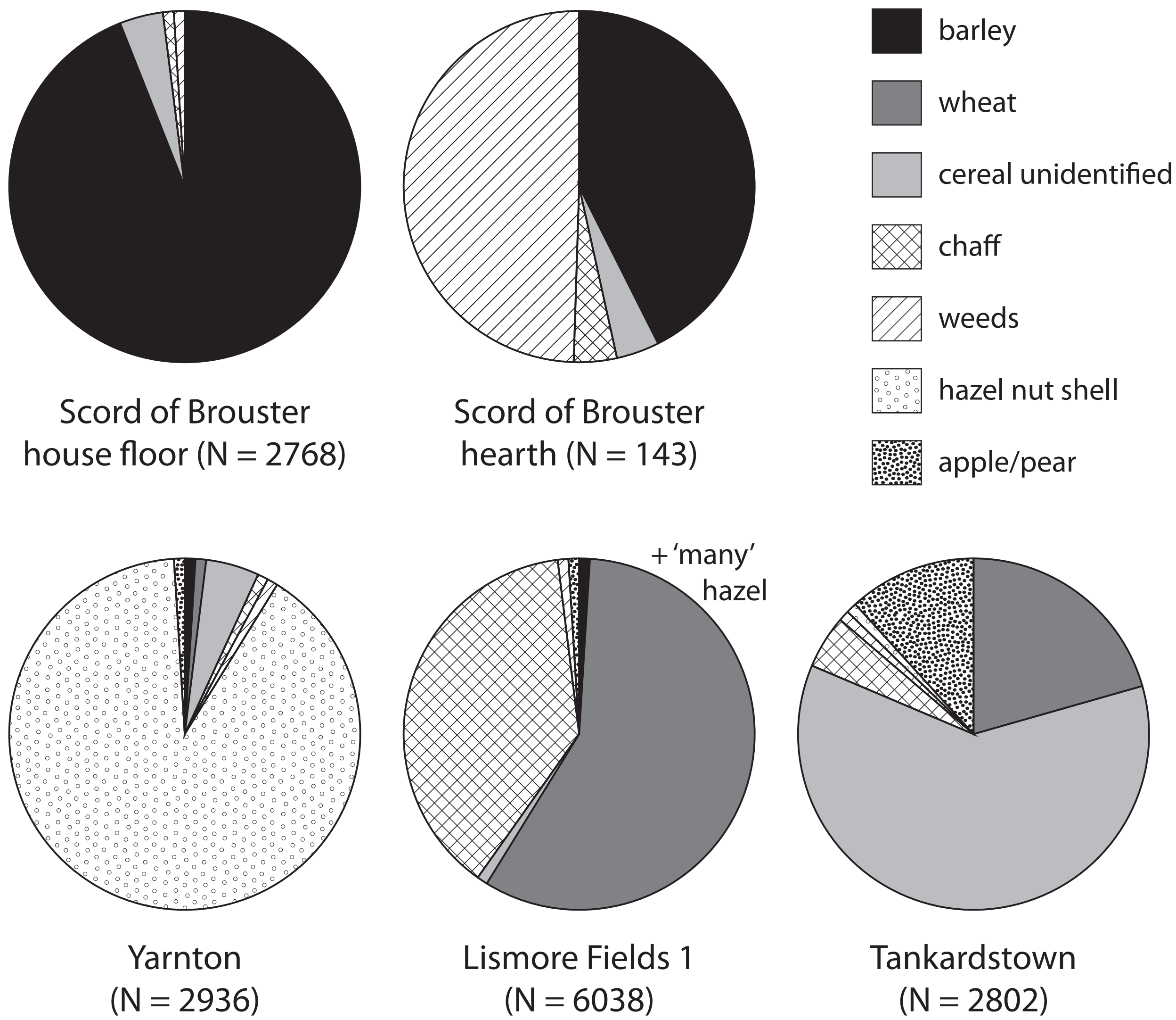
Fig. 5. Economic remains from selected continental Neolithic sites in the area north of the LBK. Top: histogram showing relative frequency of the main food mammals from Schipluiden (Netherlands), Hüde I TRB level (Germany), Spodsbjerg and Muldbjerg I (Denmark), and Alvastra (Sweden). Bottom: pie charts showing relative frequency of charred plant remains from Schipluiden (Netherlands), Oldenburg-Dannau LA 191 (Germany), Spodsbjerg (Denmark), Alvastra (Sweden), and Voll (Norway).

Bones: Schipluiden from Zeiler (2006, table 22.2), Hüde I from Hübner et al. (1988, tab. 16), Spodsbjerg from Nyegaard (1985, table 1), Muldbjerg I from Noe-Nygaard

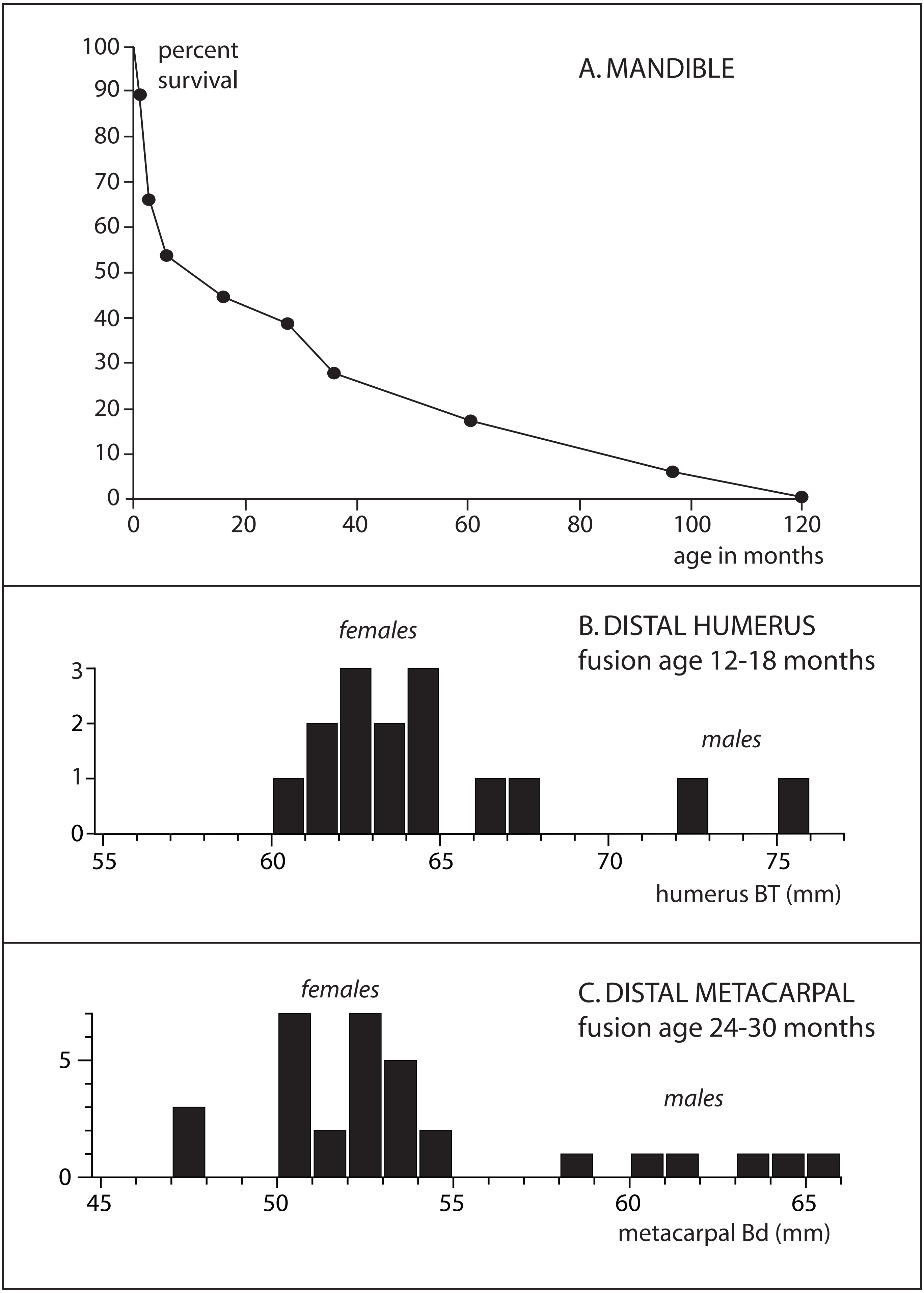
(1995, table 6), Alvastra from During (1986, table 6). Plant remains: Schipluiden from Kubiak-Martens (2006, appendix 19.2), Oldenburg-Dannau from Kroll (1981), Spodsbjerg from D. Robinson (1998, table 1), Alvastra from Göransson (1995, tables 3, 4 and 5), Voll from Soltvedt (2000, table 1).



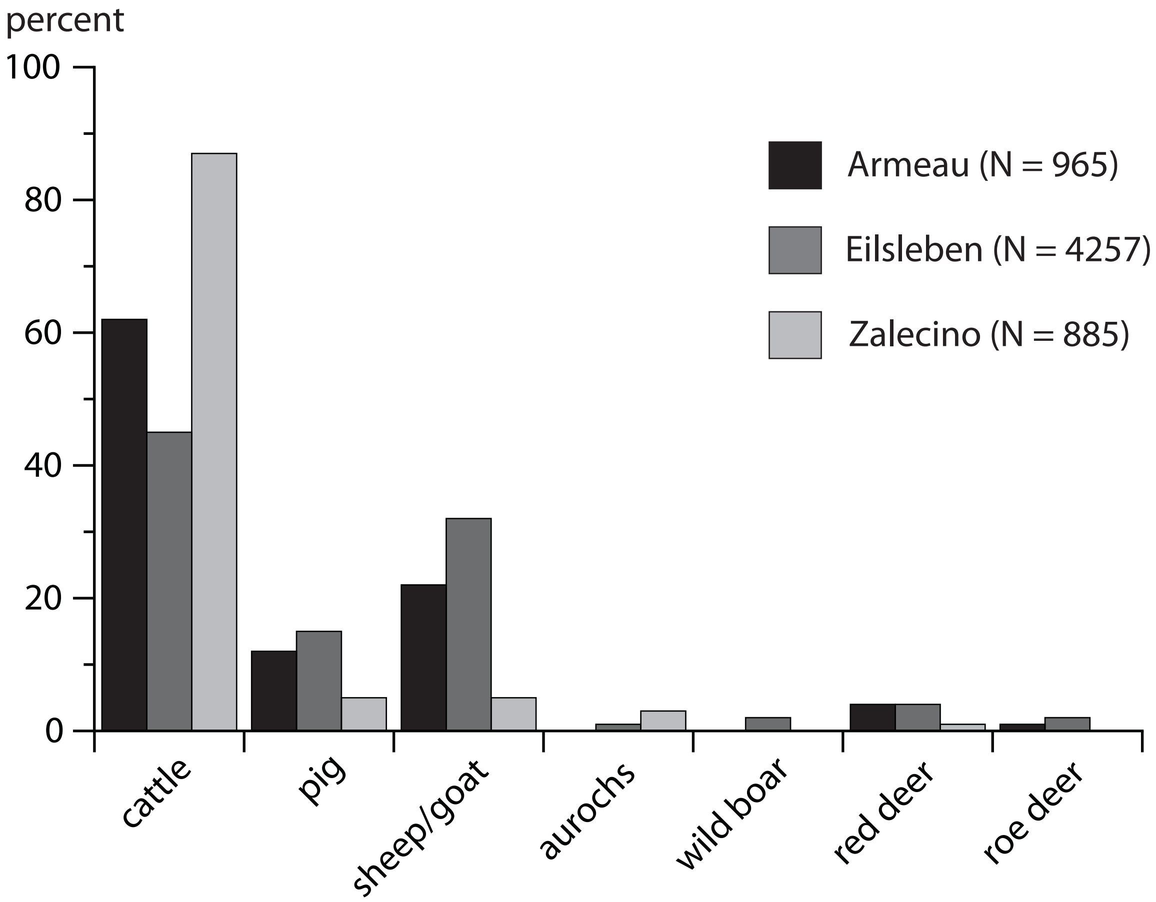
percent
70
60
50
40
30
20
10
0
Etton (N = 2325)
Hambledon Hill (N = 2371)
Windmill Hill (N = 2082)
cattle
pig
sheep/goat
aurochs
wild boar
red deer
roe deer

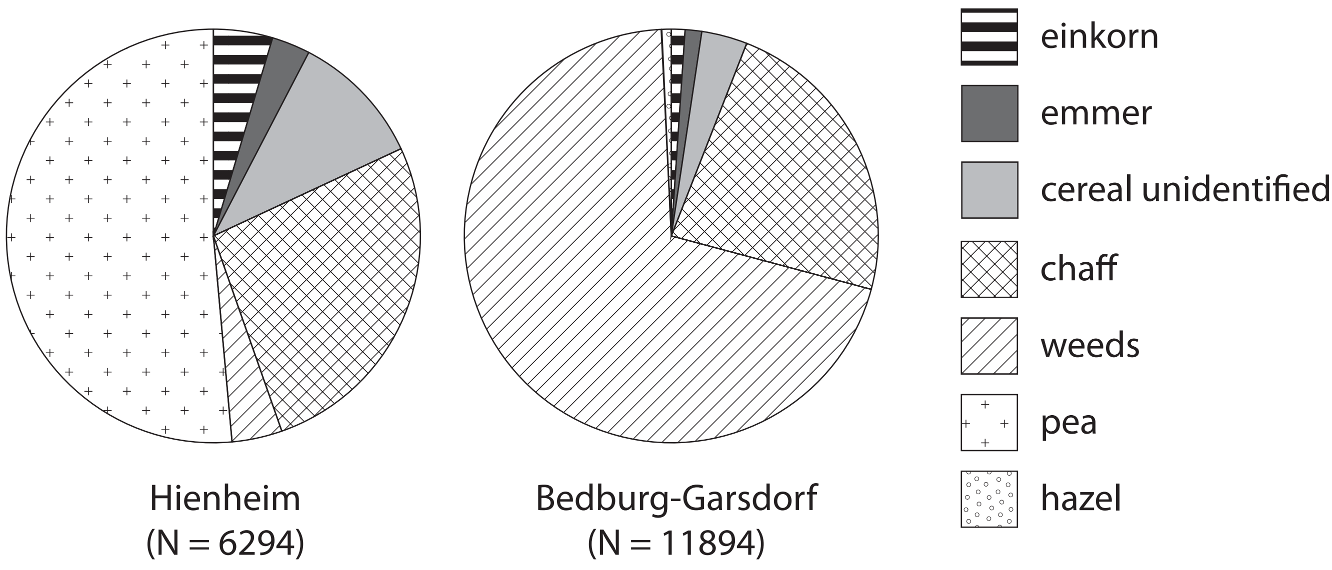


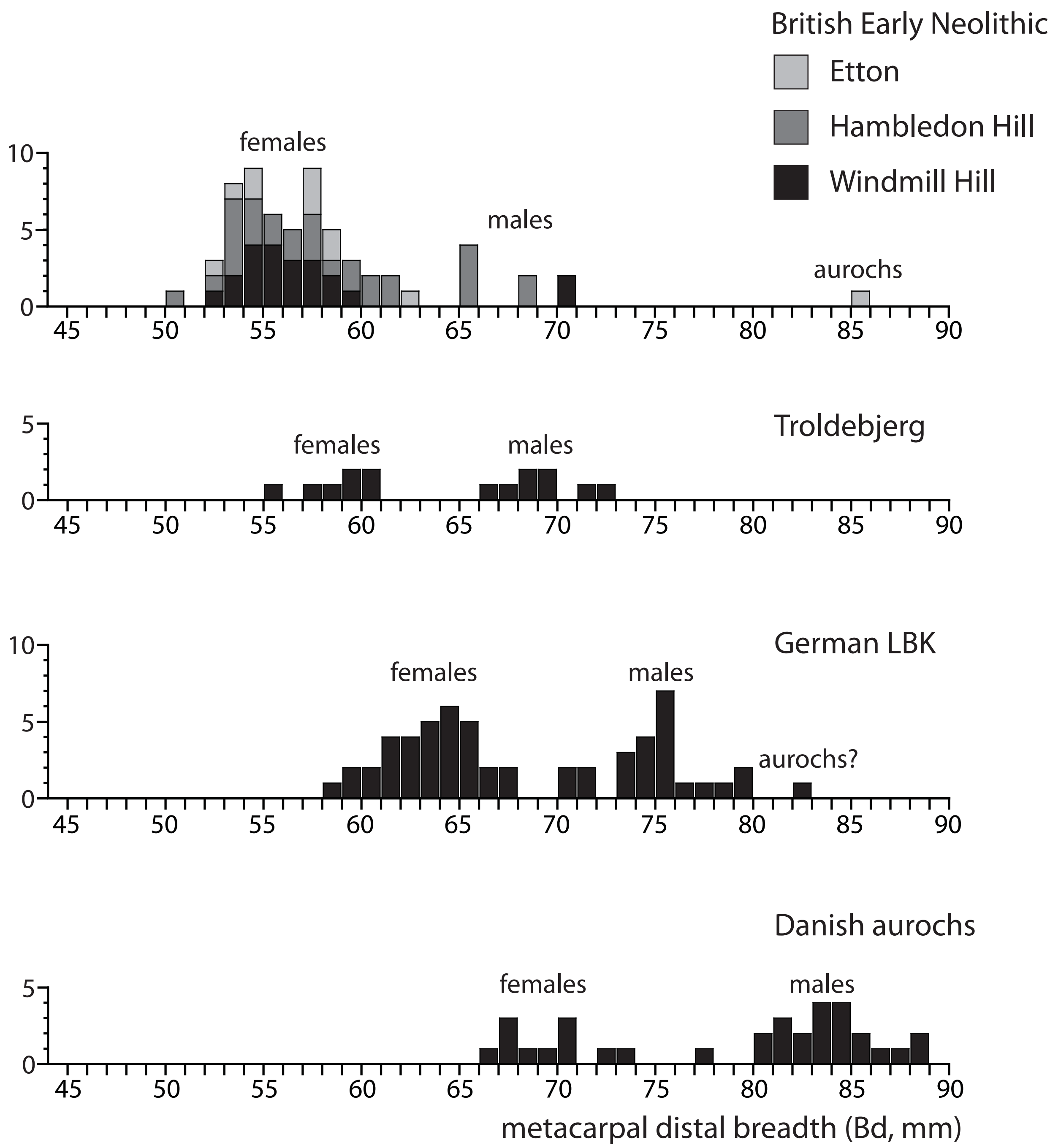
barley
wheat
cereal unidentified
chaff
weeds
hazel nut shell
apple/pear
Scord of Brouster house floor (N = 2768)
Scord of Brouster hearth (N = 143)
+ 'many' hazel
Yarnton (N = 2936)
Lismore Fields 1 (N = 6038)
Tankardstown (N = 2802)



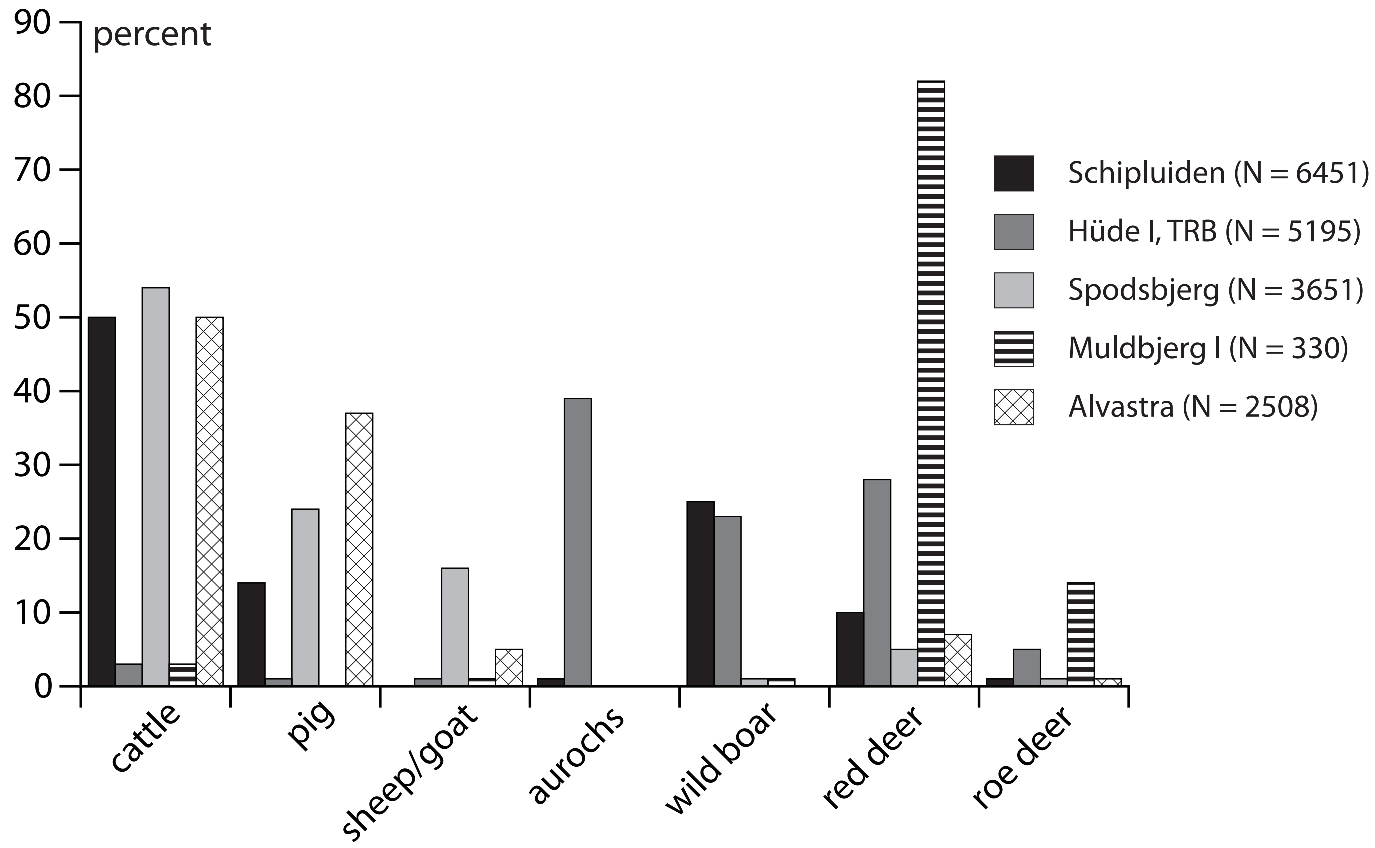
A. MANDIBLE
percent
survival
100
90
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
age in months
B. DISTAL HUMERUS
fusion age 12-18 months
females
males
3
2
1
0
55
60
65
70
75
humerus BT (mm)
C. DISTAL METACARPAL
fusion age 24-30 months
females
males
5
0
45
50
55
60
65
metacarpal Bd (mm)


percent
100
80
60
40
20
0
Armeau (N = 965)
Eilsleben (N = 4257)
Zalecino (N = 885)
cattle
pig
sheep/goat
aurochs
wild boar
red deer
roe deer

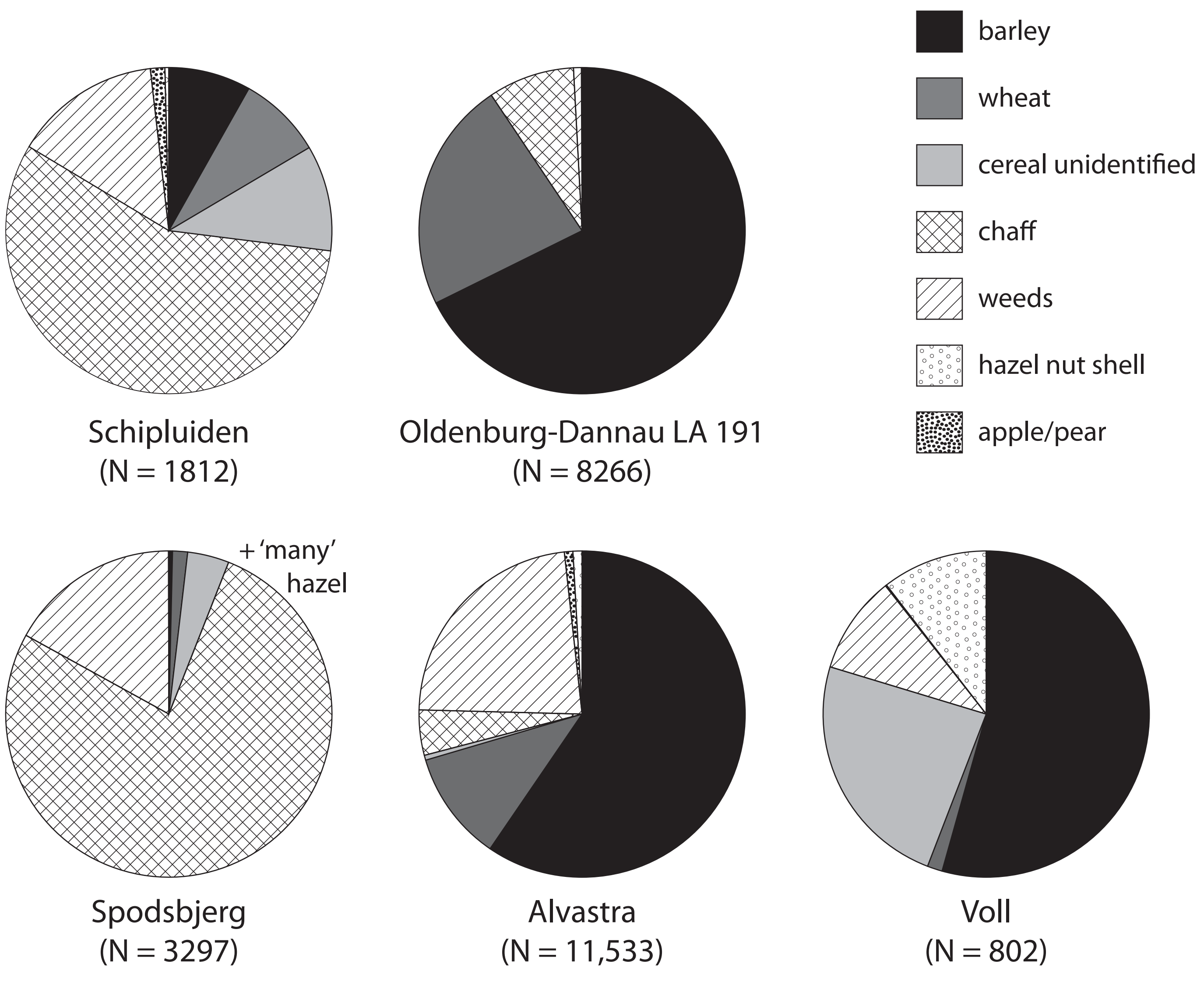

einkorn
emmer
cereal unidentified
chaff
weeds
pea
hazel
Hienheim
(N = 6294)
Bedburg-Garsdorf
(N = 11894)



British Early Neolithic
Etton
Hambledon Hill
Windmill Hill
females
males
aurochs
Troldebjerg
females
males
German LBK
females
males
aurochs?
Danish aurochs
females
males
metacarpal distal breadth (Bd, mm)



90
80
70
60
50
40
30
20
10
0
percent
Schipluiden (N = 6451)
Hüde I, TRB (N = 5195)
Spodsbjerg (N = 3651)
Muldbjerg I (N = 330)
Alvastra (N = 2508)
cattle
pig
sheep/goat
aurochs
wild boar
red deer
roe deer



barley
wheat
cereal unidentified
chaff
weeds
hazel nut shell
apple/pear
Schipluiden
(N = 1812)
Oldenburg-Dannau LA 191
(N = 8266)
+ 'many' hazel
Spodsbjerg
(N = 3297)
Alvastra
(N = 11,533)
Voll
(N = 802)