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REVIEW

Animals and People in the Netherlands' Past: >50 Years of Archaeozoology in the Netherlands

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More than fifty years ago, Anneke T. Clason published the first English-language archaeozoological study on Dutch faunal assemblages. Inspired by the anniversary of this landmark publication, this paper presents a status overview of Dutch archaeozoology organized in twelve themes (e.g. rituals, Mesolithic-Neolithic transition, medieval period). The paper also discusses the common methods applied in Dutch archaeozoology, and includes extensive supplementary material that summarizes data from gray literature in Dutch. Our aim is to provide a guide to archaeozoological questions pertaining to the Netherlands and open a window for researchers working outside the Netherlands to the highly active world of Dutch archaeozoology.

Keywords: Zooarchaeology; Archaeozoology; Dutch; the Netherlands; Anneke Clason

Introduction

It has been more than 50 years since the late Prof. Anneke T. Clason published her dissertation, *Animal and Man in Holland's Past* (Clason 1967). After that publication, Clason became *the* leading archaeozoologist in the Netherlands, as well as its international face. Her dissertation was arguably the best-known Dutch archaeozoological study in the English-speaking scholarly world until at least the early 1990s. Since the late 1960s, her colleagues and students have built a strong tradition of archaeozoology in the Netherlands, producing, interpreting and publishing an enormous amount of data. While some of these data were–and continue to be–collected in the context of academic research and higher education (IJzereef 1981; Prummel 1983; Lauwerier 1988; Brinkhuizen 1989b; Schelvis 1992; Gehasse 1995; Zeiler 1997b; Groot 2008; van Amerongen 2016), the great majority have been produced in the context of development-led archaeology. Archaeozoologists working in the commercial archaeology sector regularly record and publish massive amounts of data, in compliance with the regulations put into effect in 2007, through the Valletta Convention (Lauwerier 2017).

However, most data remain difficult to access and/or are located in the Dutch grey literature. Syntheses are scarce, and some are in Dutch and thus not readily accessible to non-Dutch speakers. The scarcity of overviews hinders efforts to train, strategize, and internationalize. Inspired by the 50th anniversary of Clason's career launch, this review article is an attempt to partly redress this deficiency by producing a widely accessible introduction for beginners in and outsiders to Dutch archaeozoology, one that documents the state of the art.

First, we provide a very brief summary of the Quaternary geographical setting of the Netherlands. Next, we explain the common methods of Dutch archaeozoology, as we consider this a fundamental prerequisite for digging further into the data. Then, we provide summaries of the 12 themes that have received the most attention from us and our predecessors over the past 50 years. The themes vary from regional (e.g. archaeozoology of terps) to chronological (e.g. archaeozoology of the metal ages) to overarching overviews (e.g. expirations and introductions). Each thematic section draws data from the most thoroughly studied, interesting and/or best-known sites and assemblages. Maps with relevant sites are provided for several sections. Site names are provided in Supplementary Table 21. The methods used vary from theme to theme and are

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provided in Supplementary Document 1. To summarize, we provide a comprehensive but concise discussion of the state of the art of archaeozoology in the Netherlands, from a longue durée perspective.

A Note on the Quaternary Geography of the Netherlands

Having a basic knowledge of the Quaternary evolution of the country's dynamic landscapes is crucial to understanding the Dutch archaeozoological record. Luckily, the Dutch landscape is arguably one of the best and most systematically investigated landscapes in the world. In the Late Pleistocene, most of the Netherlands was part of Doggerland, a vast area of land connecting Britain and continental Europe. In the early Holocene, the coastline lay farther west than it does at present, and around 9000 BC, the relative sea level of the southern North Sea was 26 m below the present level. As sea levels continued to rise, at an average speed of ~0.80 m per century, peat was formed in the pericoastal zone due to the wet conditions that prevailed there, and a major part of the Netherlands became part of the tidal basins of various river systems. In the west, the coastline reached its easternmost location around 3850 BC. In the north, the dune barriers of the Wadden Sea Islands (with the exception of the island of Texel) have been in place since the Iron Age and the Roman period (Vos 2015). Around 500 BC, the sea-level rise had decreased to about 0.10–0.05 m per century and, due to a sediment surplus in the coastal zone of the western part of the Netherlands, the dune systems were shifting westwards again. In the northern part of the Netherlands, salt-marsh areas were growing, and from the Early Iron Age onwards, dwelling mounds (known in Dutch as *terpen* or *wierden*) were created to protect people against floods. Artificial ditches and channels made peat areas habitable. This was the beginning of centuries of reclaiming land from the sea that the Netherlands is renowned for. Works to manage the landscape continued under the Romans, who incorporated the southern part of the country into their empire.

The meandering river channels shifted continuously, with new watercourses being developed through the deltas until the Middle Ages, when humans started to embank the rivers to control the watercourses (Vos 2015). Anthropogenic impact on the landscape increased from the High Middle Ages onwards (since the 12th century). Dykes were constructed along the salt marshes and floodplains of coastal and river regions, and the peat landscape almost disappeared (Vos 2015). Estuary systems (including those of the Rhine and the Meuse) still dominate, creating a complex and dynamic landscape. Continuous and extensive waterworks coupled with a completely tamed 'nature' define the Dutch landscape today.

Methods in Dutch Archaeozoology

Dutch archaeozoology has been both innovative and practical in terms of methodology.

Methodological innovations born out of the necessity to interpret Dutch assemblages have become fundamental methods worldwide. Examples include Lauwerier on recording butchery marks (1988: 181–212) and pig (*Sus domesticus*) seasonality (1983); Prummel and Frisch (1986) on the distinction of sheep (*Ovis aries*) and goat (*Capra hircus*); Prummel (1987b, 1987a, 1988, 1989) on the identification of foetal skeletal elements of cattle (*Bos taurus*), horse (*Equus caballus*), sheep and pig; Schelvis (1992) on mites (Arachnida); and Jans (2005) and Cuijpers (2009) on the application of histology.

Practical methods can be categorized into on-site, recording and interpreting, publishing and post-analysis storage methods.

At prehistoric sites, finds are usually collected through trowelling (known as hand collecting) and sieving. For later periods, a combination of hand collecting and sieving is the norm. Precise taxonomic identifications are prioritized in faunal analysis. Researchers both in public and in commercial institutions are keen on using and improving reference collections across the country. Archaeozoological reference collections are located in Amsterdam (Department of Archaeology, University of Amsterdam), Leiden (Faculty of Archaeology, Leiden University), Groningen (Groningen Institute of Archaeology, University of Groningen) and Amersfoort (Rijksdienst voor het Cultureel Erfgoed (RCE), the Dutch government's cultural heritage agency).

The methods used in recording and reporting are largely in line with methods used elsewhere in Europe, especially in continental Europe, and thus can be considered standardized. Standardization is further achieved through frequent contact among the small and well-organized archaeozoological community (through a yearly workshop meeting of archaeozoologists organized by the RCE and such organizations as the Biologisch Archeologisch Platform (the biological archaeology platform), and a recent Dutch textbook/manual on archaeozoology (Groot 2010)). While not dictated, best practices are recommended by the RCE (Lauwerier 2010). The Dutch archaeology quality standard (*Kwaliteitsnorm Nederlandse Archeologie*), based on heritage legislation and self-regulation, sets minimum standards for specialist work in archaeology. Since 2017, quality has been ensured through a certification-based system.

Tooth wear and eruption are generally recorded following Grant (1982), in combination with Hambleton (1999) or Habermehl (1975). Fusion is recorded following Habermehl (1975), Silver (1969), Zietschmann and Krölling (1955) and Johansson and Hüster (1987), as visualized by the Archäologisch-Zoologische-Arbeitsgruppe Schleswig-Kiel (Reichstein (1991: 21–22)). Number of fragments (*Aantal Fragmenten*) is the most common unit of quantification. Although it is sometimes equivalent to NISP (Number of Identified Specimens), it usually refers to the number of fragments rather than specimens. Bone weight frequently accompanies fragment counts in reports. Other quantification methods or derived types of data used to estimate relative abundance or importance (e.g. MNI = Minimum Number of Individuals), etc., are not in general use.

Most standardized biometric measurements are omitted, especially in development-led research, with the exception of the greatest length of complete long bones (Von den Driesch 1976). These are then converted to

withers heights following von den Driesch & Boessneck (1974) and Matolcsi (1970) for cattle; May (1985) for horse; Harcourt (1974) for dog (*Canis familiaris*); and Teichert (1969, 1975) for pig, sheep and goat. In general, pathologies, butchery, burning and gnawing marks are recorded and briefly described in reports. Occasionally, the publication by Lauwerier (1988) is used to describe butchery marks. A description of the preservation of the bone material is usually given, often referring to Behrensmeyer (1978) or Huisman *et al.* (2009), and sometimes a description of the fragmentation is given, as percentages of the elements present (Groot 2010: 99, Table 7.2).

Archaeozoological reports produced through development-led research are, by default, uploaded to Archis (a database managed by the RCE containing information on rescue excavations in the Netherlands) and often also to the electronic archives (known as e-depot DANS) administered by the Royal Netherlands Academy of Arts and Sciences (KNAW) (2018). BoneInfo, a system with archaeozoological meta-data operated by the (RCE) is the best starting point to obtain regional and chronological absence/presence information about taxonomic groups (Lauwerier & de Vries 2004). The post-analysis storage of archaeofaunal assemblages is the responsibility of provincial and local authorities. Assemblages are submitted to provincial heritage depots along with metadata (Supplementary Table 1) (Royal Dutch Academy of Sciences (KNAW) 2018, RCE 2018).

The Archaeozoology of the Pleistocene

Pleistocene/Palaeolithic faunal remains are investigated to address questions about the date ranges for the occurrence of Pleistocene species, the role of animals in hominin/human subsistence, bone tool manufacture, and hominin/human environment.

Hotspots that yield Pleistocene fauna are the North Sea area (both the sea and the coast) and the river valleys. The fossil record is, however, rather fragmented (van Kolfschoten 2001). Even boreholes, such as the ones at Zuurland, with an extremely rich, stratified small-mammal record show large hiatuses in time (van Kolfschoten 1998; van Kolfschoten & Tesakov 1998; van Kolfschoten, Tesakov & Bell 2018). Rich faunal assemblages collected *in situ* from stratigraphically well-embedded deposits are limited: the localities Tegelen and Tegelen-Maalbeek yielded fossil vertebrates from the onset of the Early Pleistocene, and Maastricht-Belvédère yielded faunal remains from the later part of the Middle Pleistocene and the late Pleistocene. However, a number of localities (e.g. Bavel, Dorst, Neede, Wageningen-Fransche Kamp, Rhenen, and Orvelte) yielded smaller *in situ* assemblages dated to the Pleistocene.

Most of the Pleistocene faunal remains are from stratigraphically disturbed contexts; they were collected, for example, from sediments dredged from sand and gravel pits throughout the country (e.g. Woerden, Rhederlaag) or from beaches, such as Maasvlakte 1, Maasvlakte 2, Zandmotor and Hoek van Holland, where sediments from the bottom of the North Sea have been redeposited to create artificial land or sea defences (van Kolfschoten & Vervoort-Kerkhoff 1999). The Brown Bank and the Eurogeul appear to be very rich in fossil remains. While the majority of the North Sea fossil assemblages date from the late Pleistocene, both early Pleistocene and early Holocene fossils have been identified. A similar situation exists more inland, in the southern Netherlands, where fossil vertebrate remains are found in mixed Pleistocene and Holocene deposits (de Jong 2012).

The Pleistocene (2.6 Ma to 10,000 BP) deposits in the Netherlands are rich in faunal remains, including a large variety of small and large mammal species (**Figure 1**). The large mammal record includes carnivores (e.g. lion (*Panthera* sp.), sabretooth cat (*Homotherium latidens*), hyena (*Crocuta* sp.), bear (*Ursus* sp.), wolf (*Canis* sp.), and wolverine (*Gulo* sp.)), at least five different elephants (assigned to the genera *Mammut, Mammuthus* and *Palaeoloxodon*), different horses (Equidae), at least six different rhino species (Rhinocerotidae), tapir (*Tapirus arvernensis*), wild boar (*Sus scrofa*), hippopotamus (*Hippopotamus* sp.), a large number of deer species (Cervidae), and a variety of bovids (Bovidae) (van Kolfschoten 2001).

The role of reindeer (*Rangifer tarandus*) in Late Palaeolithic cultures, a persistent issue in Palaeolithic research in Europe, has also been tackled in Dutch contexts. Campsites of Late Pleistocene hunter-gatherers in northern Germany and Denmark have yielded reindeer bones radiocarbon-dated to the Hamburg (13,000–15,500 BC) and Ahrensburg (11,000–9800 BC) cultures (Lanting & van der Plicht 1996). Characteristic for these cultures are flint arrow heads which were most probably used for reindeer hunting. These types of artefacts have also been found in the Netherlands, but not in association with reindeer remains. In order to get a better idea of the occurrence and distribution of the reindeer in the Netherlands during the Pleistocene, mammalian fossils have been radiocarbon dated (van Kolfschoten et al. 2011). This research showed that the reindeer remains from the Netherlands and the North Sea are older than ca. 30,000 years (Kuitems 2007; van Kolfschoten et al. 2011; Lauwerier & Deeben 2011; Lauwerier, Prummel & van Kofschoten 2016; Lanting & van der Plicht 1996) (**Figure 2**). The mammalian fauna from the late Pleistocene (Younger Dryas and Preboreal, 11,500 to 9,000 BP) is dominated by red deer (*Cervus elaphus*), aurochs (*Bos primigenius*) and beaver (*Castor fiber*), while reindeer seems to be absent (Snijders & Broertjes 2016: 32–33; De Jong 2016). This absence of reindeer has led to the hypothesis that the so-called reindeer hunters had no reindeer to hunt in the Netherlands (Lauwerier, Prummel & van Kolfschoten 2016). The Late Pleistocene biotope in the Netherlands was apparently no longer suitable for reindeer herds, whereas that in northern Germany and Denmark still was. More radiocarbon dates are needed to test this hypothesis and further investigate the subsistence strategies of the late Pleistocene and early Holocene hunter-gatherers.

The Mesolithic–Neolithic Transition

Animal remains are central to the study of Mesolithic–Neolithic transitions. This is also the case for the Netherlands and for north-western Europe in general (Raemaekers

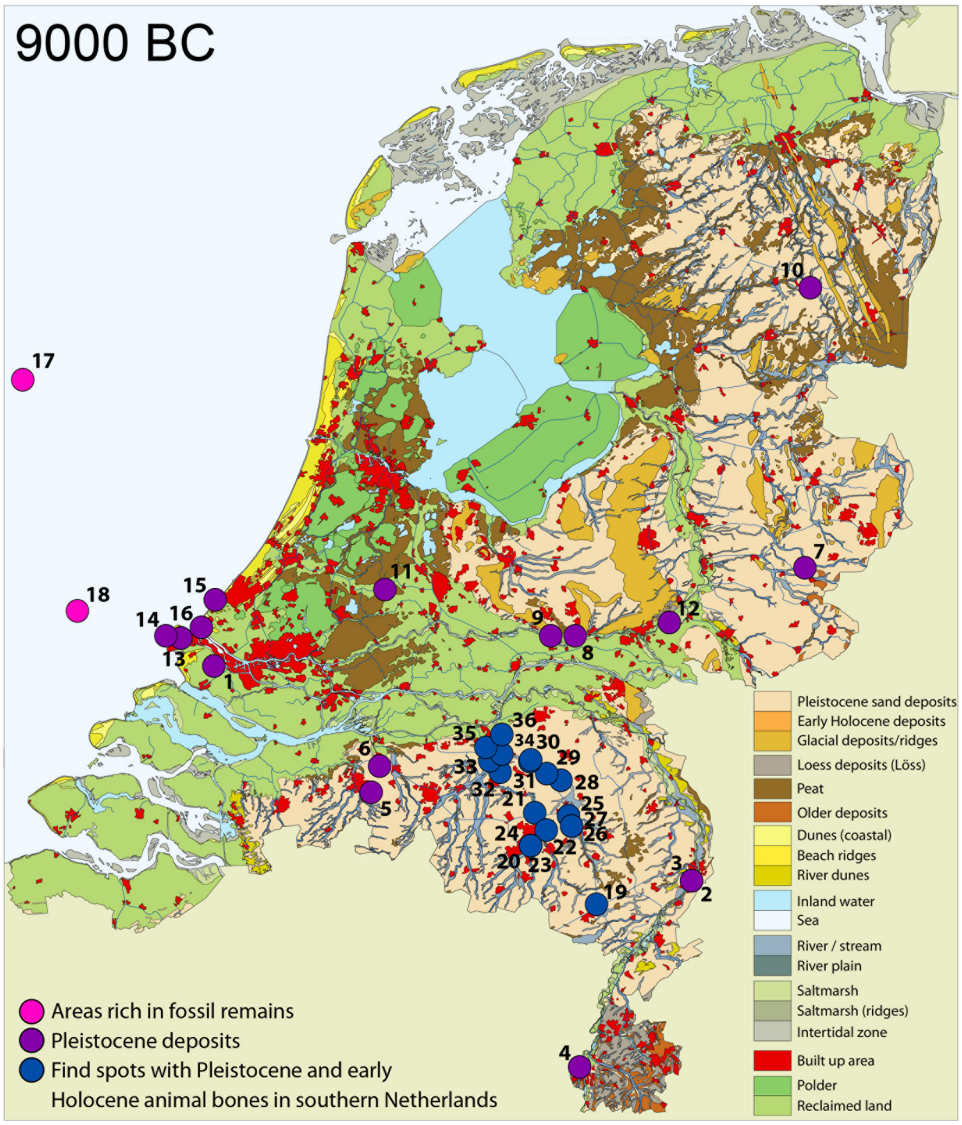

Figure 1: Map with Pleistocene localities discussed in text.

2003; Rowley-Conwy 2014). Although there is clear consensus that ceramics arrived in the Netherlands before plant and animal husbandry, the mechanisms, sequence and timing of the adoption of plant and animal husbandry are still under investigation (Cappers & Raemaekers 2008; Rowley-Conwy 2011; Rowley-Conwy 2014). Sites with Mesolithic–Middle Neolithic A (8400–3400 cal. BC) deposits are scarce (Supplementary Table 2; **Figure 3**), and assemblages are often small (Supplementary Table 3). Evidence is missing altogether from the sandy areas that cover most of the eastern and southern parts of the Netherlands, where organic remains are not preserved (Vos & de Vries 2013: maps 5500 and 3850 BC).

The Mesolithic–Neolithic transition research focuses on the period between 5600–4000 BC. The higher parts of the southern Netherlands, on the other hand, as exemplified by the site Elsloo-Koolweg (Lauwerier & Laarman 2015) (5500–4900 BC), are already settled by farmers associated with the Linearbandkeramik culture, who husbanded sheep, goat, cattle and pig. In the Dutch wetlands, ample remains of pike (*Esox lucius*), cyprinids (Cyprinidae), perch (*Perca fluviatilis*), wels catfish (*Silurus glanis*), beaver, otter (*Lutra lutra*), ducks (Anatidae), swans (*Cygnus* sp.) and geese (Anatidae), wild boar and red deer, all associated with freshwater, demonstrate the significance of freshwater faunal resources in the life of humans throughout the period (van Wijngaarden-Bakker et al. 2001; Oversteegen et al. 2001; Clason & Brinkhuizen 1978; Zeiler 1997b; Prummel et al. 2009b; Gehasse 1995; Kranenburg & Prummel in press), and nitrogen and carbon isotopic ratios in human remains confirm this (Smits et al. 2010; Smits & van der Plicht 2009).

There is no evidence for overexploitation of frequently hunted species. For example, in several sites, beavers are abundant, with butchery marks indicating their intensive use as a source of food and fur, but they are almost always adult individuals, indicating that the beaver population remained stable despite human pressure. Mesolithic kill sites in the north, however, such as Jardinga and Balkweg, with assemblages dominated by aurochs and red deer, deviate from this general pattern of focus on aquatic resource exploitation (Prummel et al. 2002; Prummel & Niekus 2005; Prummel et al. 2009b; Prummel & Niekus 2011). While properties of the landscape and availability

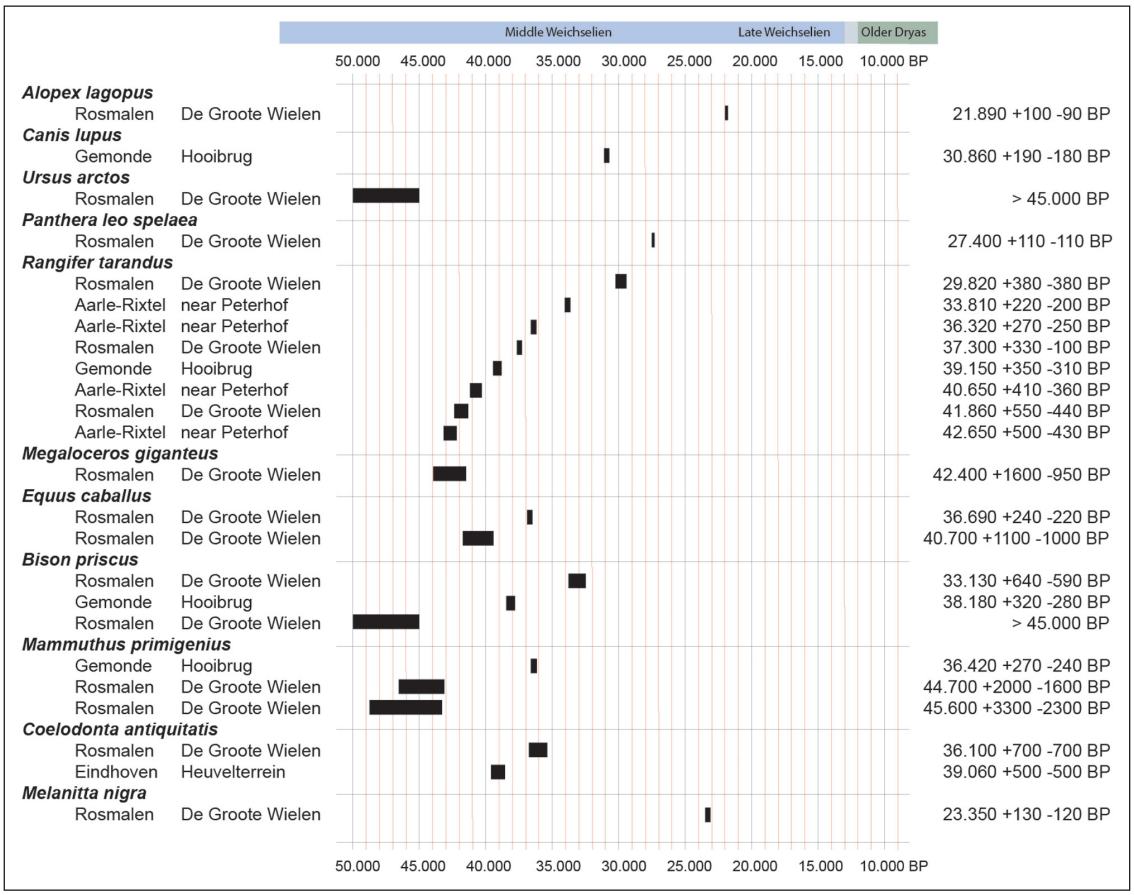

Figure 2: Radio-carbon-dated Pleistocene faunal remains from the southern Netherlands (De Jong 2016).

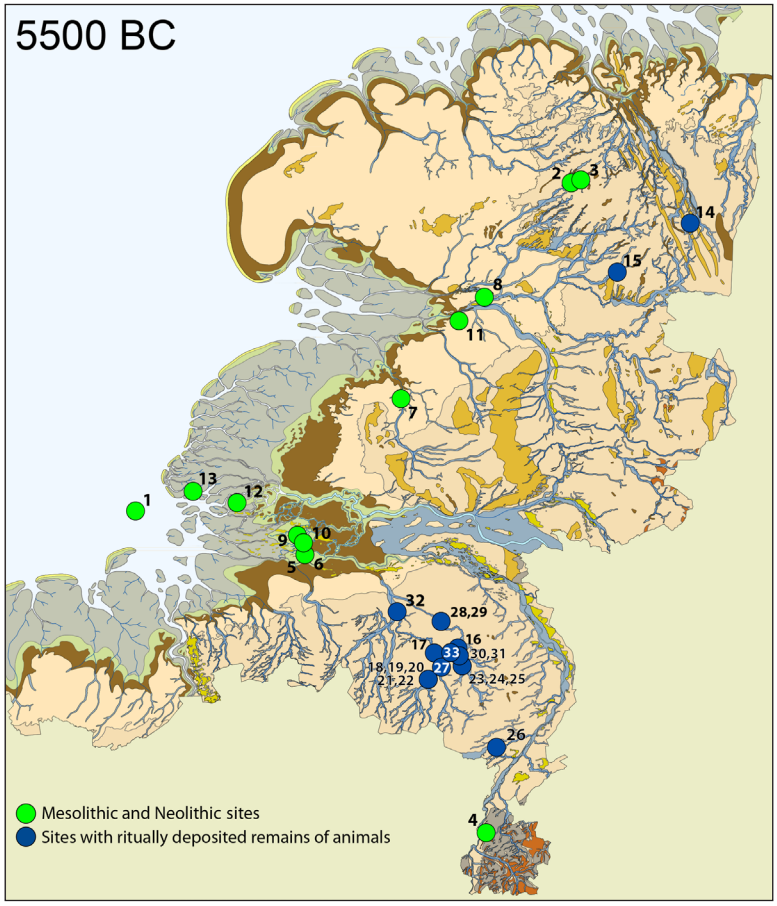

Figure 3: Map with Mesolithic and Neolithic sites discussed in text.

of resources explain some patterns in the faunal exploitation during the Mesolithic, other patterns cannot be explained by optimal exploitation of whatever is available in the environment. For example, even at sites near the North Sea coast, e.g. Yangtze Harbour, remains of marine fish are rare (Zeiler & Brinkhuizen 2015). Wild horse (*Equus ferus*) seems to have been part of the fauna in the early Holocene as well, but in very small numbers (Laarman 2001; Zeiler 1997b; Zeiler & Brinkhuizen 2016).

Wetland foraging remains an important form of subsistence between 5400 and 4000 BC. The first few remains of morphologically domestic animals apart from dog in the Dutch wetland sites come from deposits dated after 4400 BC and represent cattle, sheep, goat and pig (Oversteegen et al. 2001; Louwe Kooijmans 2001). The identified mammal assemblages from the wetlands that date between 4400 and 3400 BC contain, on average, one third morphologically domestic mammals (mainly cattle and pig and a few sheep) and two thirds wild mammals (in terms of the number of fragments) (Gehasse 1995; Zeiler 1997b; Prummel et al. 2009a; Kranenburg & Prummel in press). Direct radiocarbon dates on a few caprine remains from key transitional sites indicate this taxon's presence in the period 4400–4100 BC (but note that there is a plateau in the radiocarbon curve at the end of the 5th millennium BC), but sheep/goat remains do not appear in the Dutch wetlands again until 2500 cal. BC (Çakirlar et al. in press). MtDNA does not show a presence of Near Eastern lineage in any of the suids in the period 4400–4000 BC (Larson et al. 2007; Krause-Kyora 2011; Kranenburg & Prummel in press).

The changing relationships between humans and animals during this crucial period need to be explored in greater detail, with new methods and from multi-disciplinary perspectives.

The Subsistence Economy of the Metal Ages

The metal ages (the Bronze Age (2000–800 BC) and the Iron Age (800–12 BC)) have been important research foci in the Netherlands. The landscape was very suitable for animal husbandry, with large areas ideal for grazing. In general, the metal ages are characterized by small farmsteads where people kept cattle, sheep, and goat, followed in terms of proportion of fragment counts by pigs, horses and dogs (**Figure 4**), but within this general pattern substantial changes must have occurred, relating to social and

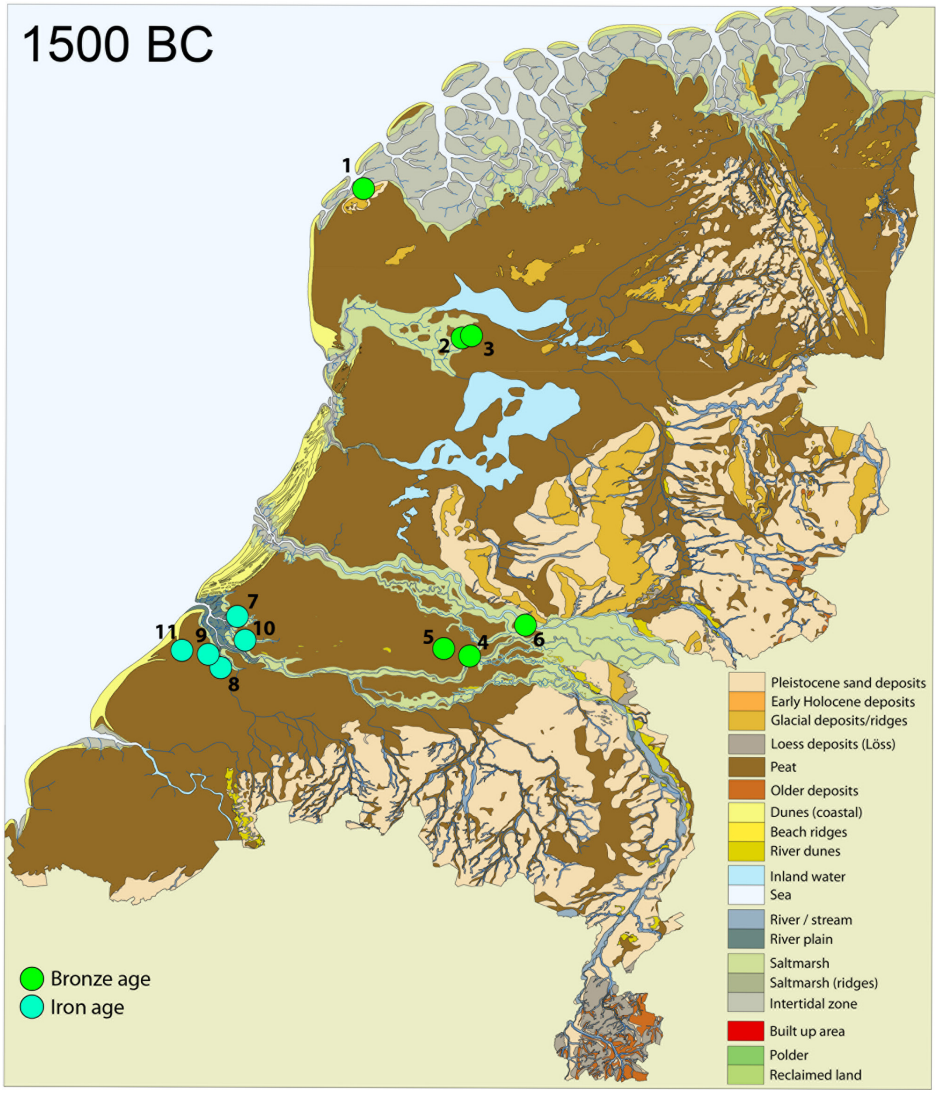

Figure 4: Map with Bronze Age and Iron Age sites discussed in text.

technological innovations. Although the relative proportions of domestic animals vary among Bronze Age assemblages, the general pattern that emerges is an emphasis on cattle breeding (**Figure 5**) (van Amerongen 2016).

Most archaeozoological research focusing on the metal ages of the Netherlands investigates diachronic change, testing old hypotheses. Research suggests, for example, that with the emergence of a crop husbandry system known as Celtic fields in the Late Bronze Age, the interdependence between crop and animal husbandry became more pronounced, with crops providing staple food and animals providing meat and secondary products (van den Broeke 2005; Kooistra & Maas 2008). Indeed, preserved trackways at the present island of Texel (Woltering 2001) indicate that the landscape was also husbanded to facilitate overland connectivity. Isotopic studies suggest that these routes may have been used to transport live animals (e.g. Brusgaard 2014; Brusgaard, Fokkens & Kootker 2019).

A claim that there was an emphasis on milk production (van Wijngaarden-Bakker 1988) was tested by recent research, which showed no clear economic specialisation in a particular use of livestock in the metal ages (van Amerongen 2016; van Dijk 2015). This probably also holds true for the Iron Age, because the farmstead settlement pattern continues. However, the significant changes in culling patterns that are evident towards the end of the Late Iron Age may point at adjustments that pre-date Roman rule (**Figure 6**). Further investigation is necessary to test this hypothesis (van Dijk 2015). The intensive

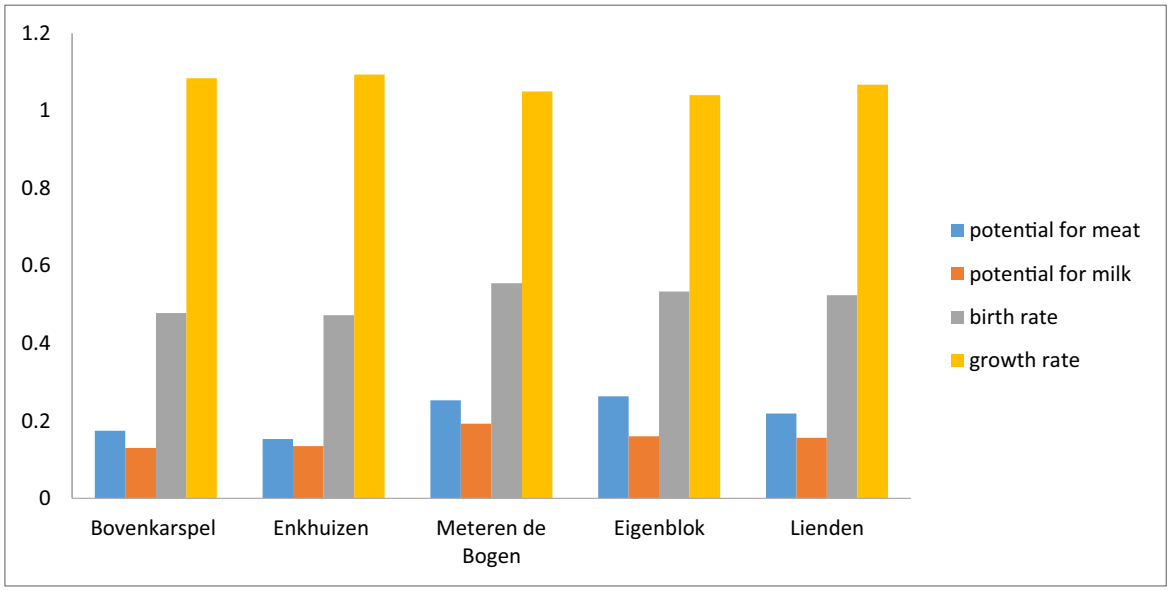

Figure 5: Use potential, birth rate, and herd growth rate of cattle from several Dutch Bronze Age sites (modified after van Amerongen 2016, Figure 9.14). Use potential is a relative value to evaluate the production potential of a herd for meat or milk (Cribb 1985).

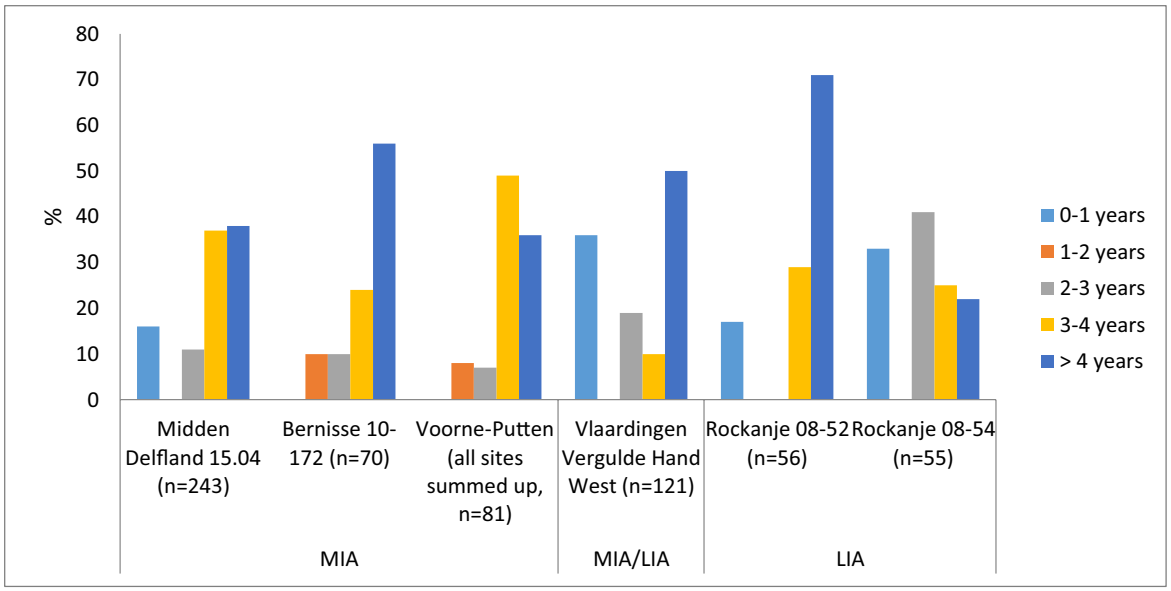

Figure 6: Mortality profile of cattle from Iron Age sites in the wetlands in the western Netherlands (after van Dijk 2015, figure 6).

animal husbandry practices in the metal ages led to inbreeding abnormalities and perhaps also to smaller-sized cattle (van Amerongen 2016: 138, 139; Manning et al. 2015). Whether the small size was an unwanted outcome or the result of a conscious strategy on the part of the farmers remains unclear.

The impact of farmers and their livestock on the environment was substantial, placing pressure on populations of wild animals (van Amerongen 2016: 259). Hunting and fishing as subsistence strategies were becoming less important. However, the wide range of wild animal species present at Bronze Age sites indicate that the intricate knowledge needed for hunting was maintained. The contribution of wild animals to the seasonal diet remained important (van Amerongen 2016: 96–104), and a possible taboo on fish, as has been suggested for Belgium and England during the Iron Age, for example (Dobney & Ervynck 2007), was not present in the Netherlands.

Although the Roman period influenced many things in the south, the type of animal husbandry system established in the Bronze Age most likely continued in rural areas until the medieval period.

The Roman Period

The Roman period in the Netherlands started in the last decades BC, when a legionary camp was constructed in Nijmegen. Between the 1st and 4th centuries AD, a series of forts were built along the south bank of the Rhine, and urban settlements developed in Voorburg and Nijmegen. Only the southern half of the Netherlands formed part of the Roman Empire (**Figure 7**). Archaeozoological work focusing on the Roman period mainly investigates the scale and extent of the Roman presence on the production and consumption of animal products in the 'Dutch part' of the Roman Empire.

An increase in agrarian production resulting from the economic demands of the army and towns was also observed in the Dutch record. Beef was the main type of meat consumed at all types of sites, but local farms probably supplied much of it (e.g. Groot, 2008; Groot et al. 2009). According to culling profiles, cattle were just as important as providers of labour and manure (Groot 2016; Groot & Deschler-Erb 2015, 2017).

A typical Roman phenomenon is the large-scale processing of cattle carcasses in towns, including in

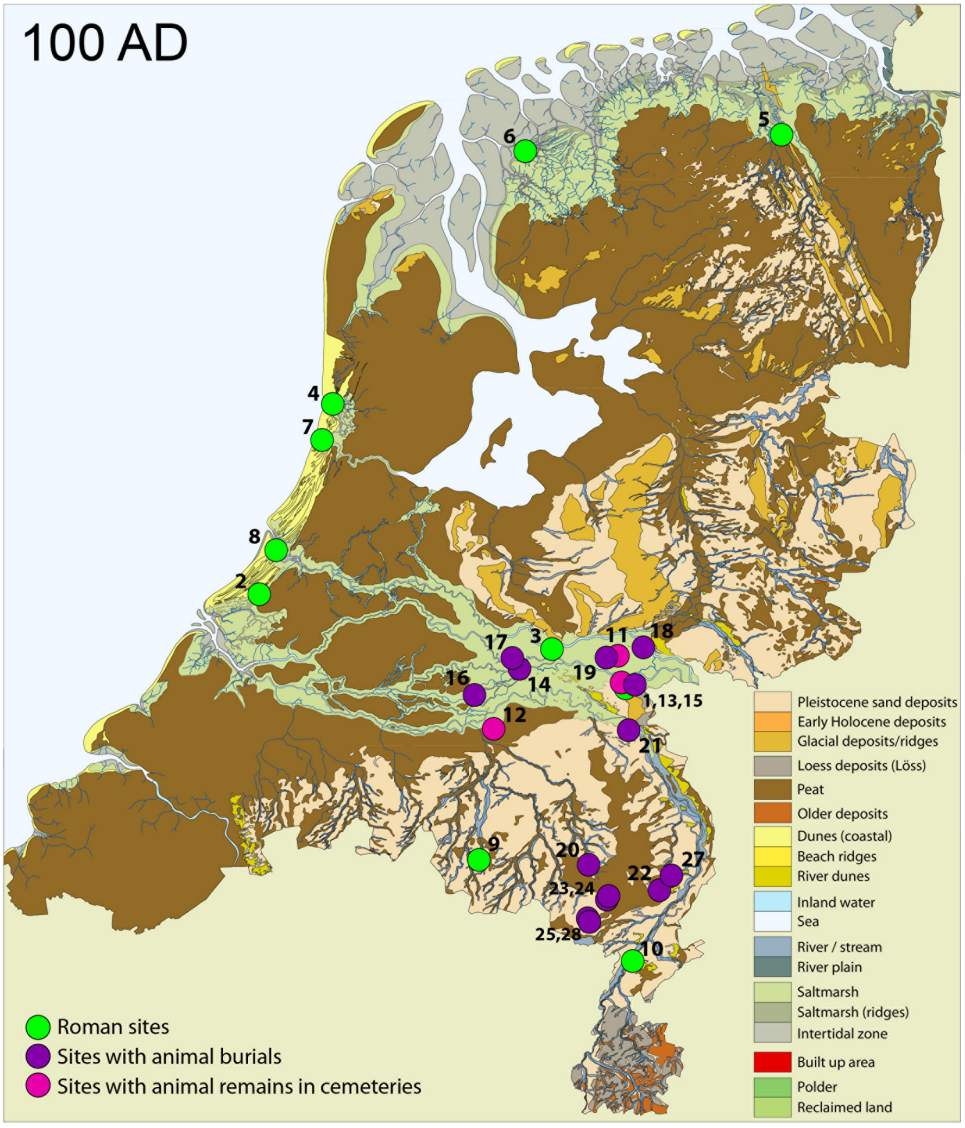

Figure 7: Map with Roman sites discussed in text.

Nijmegen (Filean 2006). Cattle also provided leather, horn, grease and bones, and the working of these materials took on an industrial character. The increased use of the meat cleaver in rural sites is reflected in an increase in chop marks on bone (Groot 2016). Meat was also preserved. Cattle shoulder blades often show butchery marks that indicate the smoking of beef shoulders, such as perforations caused by a hook. Concentrations of such shoulder blades have been found in Nijmegen (Lauwerier 1988), but smoked meat was also consumed in the countryside (Groot 2016, Lauwerier 1988: 156). The find of a shoulder blade of a horse displaying similar butchery marks, from the vicus or castellum of Kesteren (Zeiler 2005), is unexpected because horse consumption is not a typically Roman practice. Nevertheless, there is some other evidence for horse consumption in Roman contexts (e.g. Esser 2013), perhaps indicating local tastes or meat fraud.

Domestic chickens were introduced in this period. Finds in sites north of the Rhine (Lauwerier & Laarman 1999; Knol 1983; Prummel 2013; Esser & Zeiler 2013) show that chicken was also accessible to people living outside the Roman Empire. While oysters and other sea molluscs were already being exploited before the Roman period, they were now transported far inland (Groot 2016).

Occasionally, animal bones demonstrate the luxurious side of the Roman diet. A pot with preserved song thrush (*Turdus philomelos*) breasts, imported from the Ardennes, was found in the 1st-century fort on the Kops Plateau in Nijmegen (Lauwerier 1993). Preserved Spanish mackerels (*Scomber japonicus*) were found at several military and urban sites, such as Velsen and Nijmegen (Brinkhuizen 1989a; Lauwerier 1993, 2009: 162), and barracuda (*Sphyraena* sp.) was found in Nijmegen (Lauwerier 1988: 149). Edible snails (*Helix pomatia*) and garden dormice (*Eliomys quercinus*), found only at Valkenburg and the villa of Hoogeloon (Laarman 1987; Kuijper 1990, Groot 2013; Kooistra & Groot 2015), and quail (*Coturnix coturnix*), found in the Fortuna temple in Nijmegen and the villa at Maasbracht (Zeiler 1997a; Esser, Laarman & Rijkelijkhuizen 2017), can also be regarded as delicacies.

Despite these introduced and luxury foods, the diet retained much of its traditional Iron Age character, with meat consumption consisting mostly of beef and lamb. In military sites, pork is consumed more than lamb or mutton (Groot 2016; 2017). Hunting and fishing may have contributed to a varied diet, but their role was negligible in terms of calories.

The Size and Shape of Cattle and Horse in the Roman Period

Although several thousand Dutch archaeozoological assemblages have been studied over the past 50 years, many of them yielding useful metric information, only a few regional or summarising studies have been published about animal size and shape, mainly focusing the Roman period. The chronological focus is not only a result of the overrepresentation of the historic periods in development-led research, and the relatively well-preserved state, and hence reliable measurability, of the Roman-period material, but also of the interest in the debate concerning food production by farmers for the soldiers and inhabitants of towns in the 'Dutch' part of the lower Rhine delta (e.g. Groot et al. 2009; Kooistra et al. 2013). The sites considered in this section are provided in **Figure 8**.

Groot (2008, 2016) demonstrated that the average horse size in rural sites in the southern area increased during the Roman period, from 133 cm to 142 cm, indicating that local breeders tailored their production towards the military market's demand for big horses (**Figure 9**). In the Middle Iron Age the average withers height of horses in the rivers area was 131 cm (Van Dijk & Groot 2013; Groot & van Haasteren 2017). The withers height of horses increased in some places, but not everywhere, during the Roman period (Lauwerier 1988; Lauwerier & Robeerst 2001). Horses in rural settlements north of the Roman border were the smallest, with a mean withers height of 132 cm. At military sites within the Roman Empire, the average height was 142 cm, while at villa sites it was 144 cm.

In the Iron Age, cattle were usually no taller than 106 cm at the withers on average (e.g. Terpstra 1986; Knol 1983; Zeiler 2001; Groot 2005; Groot & van Haasteren 2017). In the Roman period, this did not change in the northern coastal area, which was beyond the border of the Empire (Knol 1983; Terpstra 1986; Halici 2002; Bazelmans et al. 2009). The west coast, however, saw a slight increase in average withers height, to around 110–115 cm, during the Roman period (e.g. Laarman 1983; Zeiler 1996; Lauwerier & Laarman 1999).

The trend is different in the rivers area. As far back as the Early Roman period, the withers height in the various settlements increased to a mean of 114 cm (Groot 2016). Large animals were particularly common at the consumer city of Nijmegen. This increase in average withers height was probably the combined effect of breeding for size, the importation of larger animals from other parts of the Empire, and the maintaining of old local breeds. The difference between the small animals in the north and the much larger ones in the rivers area (i.e. south of the Roman border) may reflect a different system of farming. While cattle were probably kept mainly for stock breeding in the north, in the rivers area they were kept above all to provide traction in the mixed agrarian system, and for transporting military supplies and trade goods (Lauwerier 2015).

Morphological attributes of livestock other than size have been subject to research as well. Research showed that polledness occurred mainly in the Roman period and disappeared again in the early Middle Ages in the Netherlands, unlike elsewhere in Europe, where hornless cattle had been around since the Neolithic (Schaftberg & Swalve 2015; Lauwerier 2015). Polled cattle were particularly common in the coastal area beyond the borders of the Roman Empire, while they were rare south of there (**Figure 10**). There is little evidence to explain the differences on the basis of natural selection or functional considerations; selection therefore was most likely based on aesthetic considerations or differences in perception about the appearance of a 'good' cow.

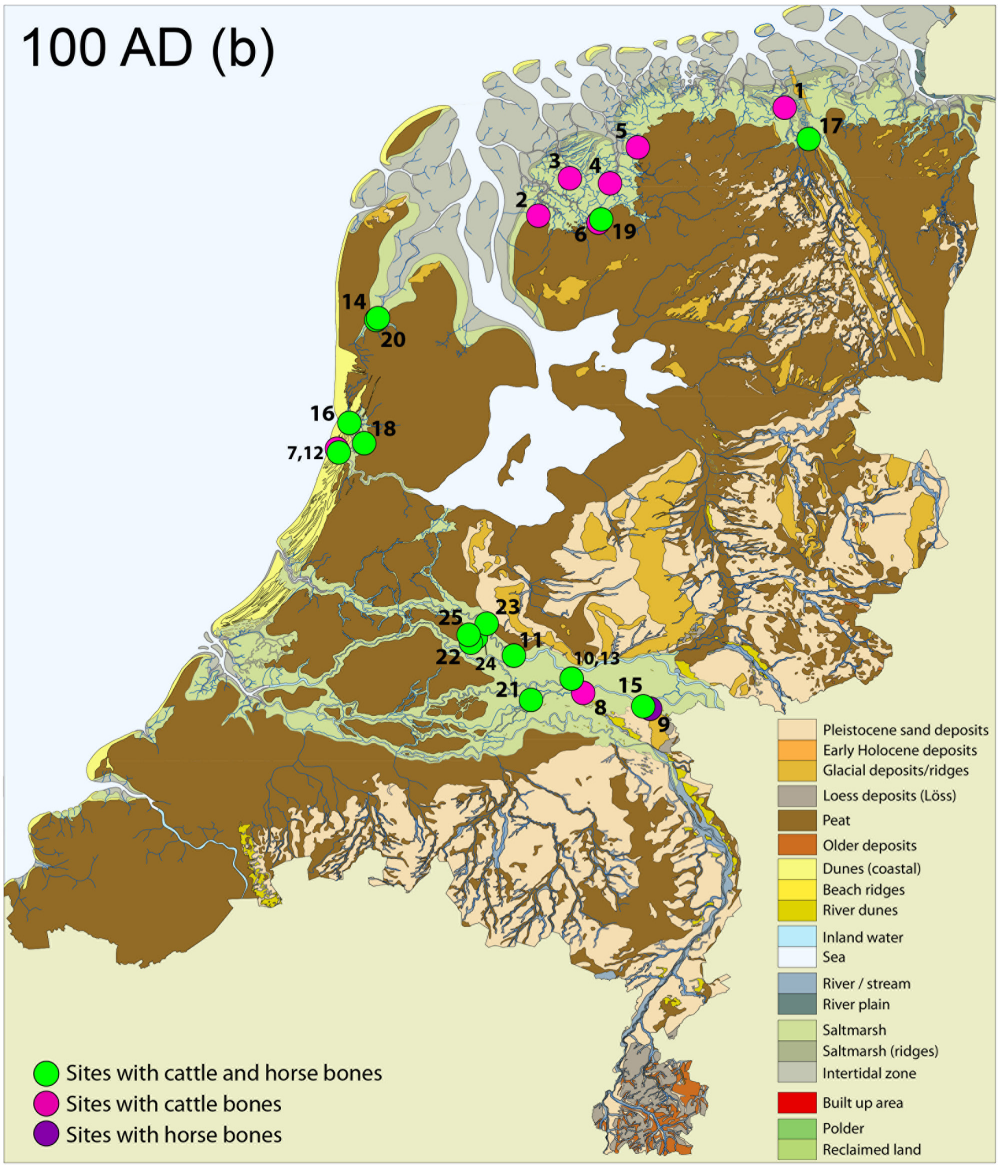

Figure 8: Map with sites discussed in Size and Shape section.

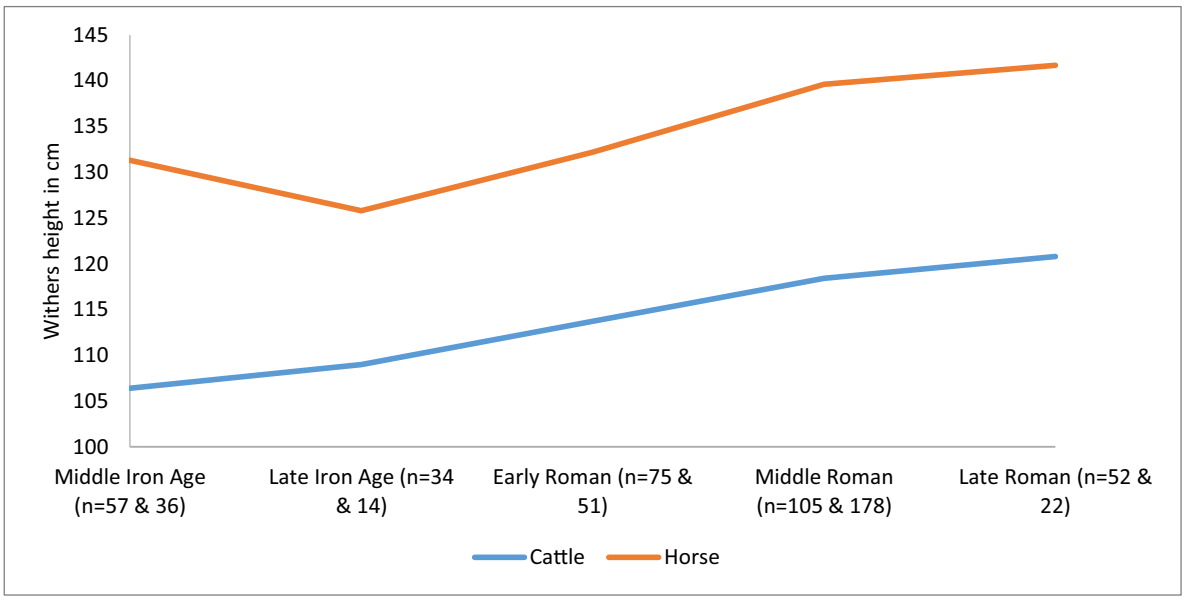

Figure 9: Withers height of cattle and horse in the Dutch rivers area. n-Values are number of specimens on which the average was based for cattle and horse, respectively.

Figure 10: Polled cow with light scurs from the Roman period at Achlum (Hullegie & Prummel 2015; photo W. Prummel).

The Early Medieval Period

Little is known about the early Middle Ages (450–525 AD) from an archaeozoological point of view, partly because Roman and medieval remains are often mixed in the stratigraphy and because the transition between the two periods occurred gradually, while, at the same time, the population declined. In the northern part of the Netherlands, the Roman and early medieval periods are often separated by an occupation hiatus, which is followed by a deviating settlement pattern (**Figure 11**). Which animal-related socio-economic trends are visible in the archaeological record in the Netherlands during the early medieval period?

During the Merovingian period (525–725 AD), clear regional differences in the representation of cattle, sheep, and pig arise (Supplementary table 4). Along the coast, from the salt marsh areas in Friesland in the north, to the marsh areas in the southwestern parts of the Netherlands, the percentage of sheep remains is high and sometimes exceeds that of cattle, which are much better represented in other regions. Changes in the archaeozoological record in the north are seemingly less pronounced, but – at least in the province of Friesland – a gradual shift from cattle to sheep emerges as well (Nieuwhof 2006; Prummel, Esser & Zeiler 2013).

In the Carolingian period (725–900 AD), the differences in the proportions of sheep and cattle are even more pronounced. With an average of 17% sheep remains, the emporium of Dorestad is an outlier in the rivers area; in the rural settlements in this area, sheep represent barely 6% on average. Striking is the dominance of pig at the Carolingian monastery of St. Salvator, in Susteren, representing almost two thirds of the animal remains (Esser & van Hees in press).

Other archaeozoological characteristics for this period are the appearance of dog and horse burials in cemeteries (Prummel 1992, 1993; van der Jagt et al. 2014). Another, unique feature is the enormous number of remains of wading birds found at Wijnaldum, a central terp mound in the north (Prummel, Esser & Zeiler 2013). Elsewhere, the avian assemblages consist mainly of chickens and of aquatic birds, such as ducks, geese, mute swan (*Cygnus olor*), and cranes (*Grus* sp.).

Fish consumption concerned mainly freshwater fish and migratory fish. Sea fish are found only in settlements along and near the coast, such as The Hague (Magendans & Waasdorp 1989), Wijnaldum (Prummel, Esser & Zeiler 2013) and Oegstgeest (Cavallo 2006, Esser 2011). Inland, fish remains are scarce and seem to have a connection with exchange and trade contacts. Remains of herring (*Clupea harengus*) and plaice (*Pleuronectes platessa*) are known from settlements near the major rivers: Leidsche Rijn (Esser 2009), Stenen Kamer/Linge (Esser & van Dijk 2001) and Dorestad (e.g. Prummel 1983; Esser, Beerenhout & Rijkelijkhuizen 2012). Imported garfish (*Belone belone*) was found in Deventer (Beerenhout 2011a).

Archaezoological data on the succeeding Ottonian period (900–1050 AD) are too scarce at the moment to enable an overview.

Animals in Castles and Monasteries

From the beginning of the 11th century, a feudal society developed in Europe, based on a philosophical theory of three sharply divided social orders: nobility, clergy and peasants. This society continued to exist until the end of the 18th century (Ervynck 2004). We know from the historical record that each of these three groups had its own function, activities and differences in diet. Archaeozoological research concerning this period often aims at testing these differences by comparing castles (known in Dutch as *borg*, *stins*, *versterkt huis*, *havezathe* or *ridderhofstad*) and monasteries in the Netherlands (**Figure 12**) (Supplementary Tables 5 and 6). The current overview is restricted to vertebrates, although molluscs were also consumed.

At all castles, meat, poultry and fish were consumed. Cattle remains dominate the assemblages except at some early castles, where pigs are more abundant

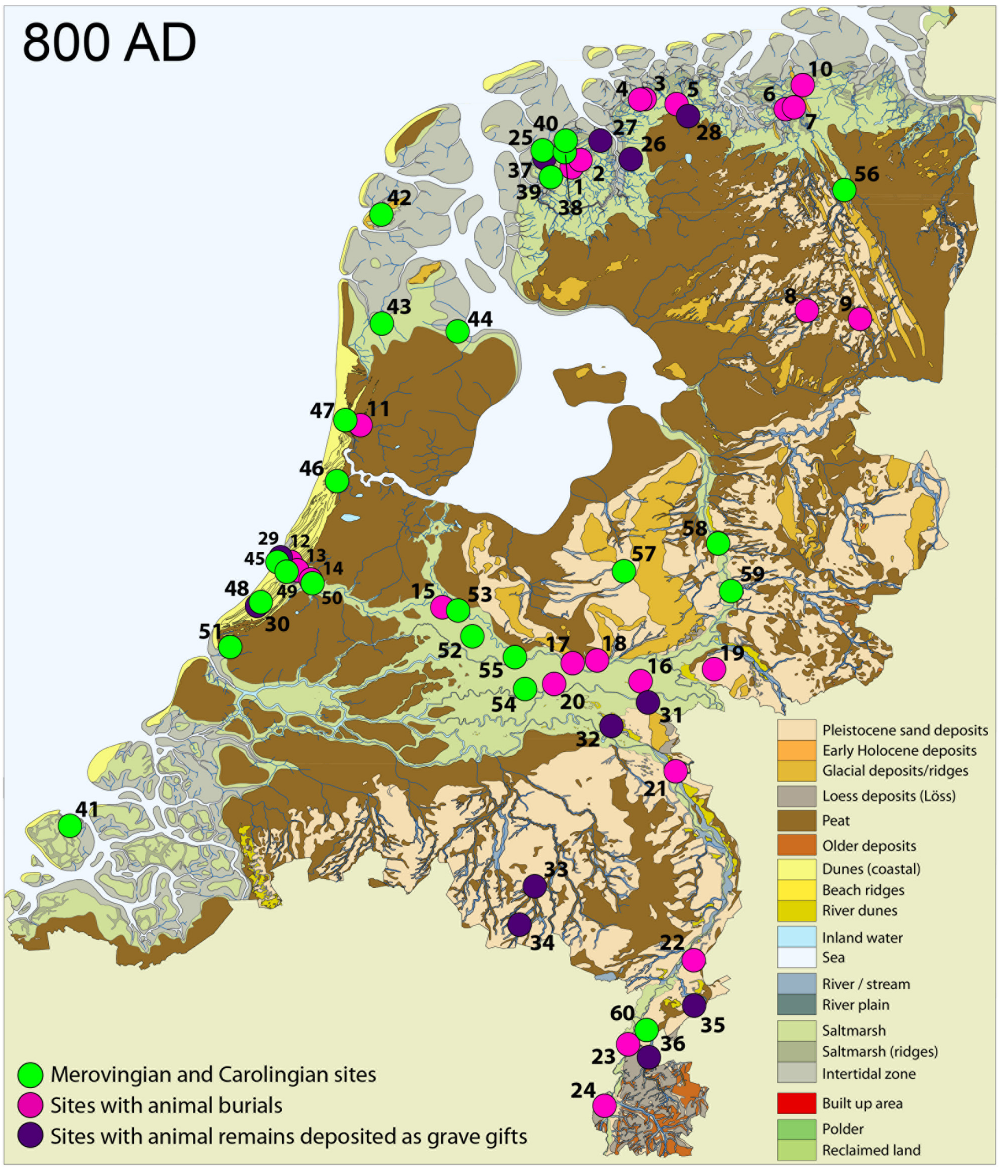

Figure 11: Map with early medieval sites discussed in text.

(Beerenhout 2011b; Esser, Kootker & van der Sluis 2014; Rompelman & Eeltink 2011; Cavallo 2011). The nobility distinguished themselves from the other orders by their hunting privileges. Large game hunting is visible in the presence of wild boar and several deer species at some of the castle sites (Supplementary Table 7). But, generally, remains of large game are scarce and those of small game, such as hare (*Lepus europaeus*) and, from the 13th century onwards, rabbit (*Oryctolagus cuniculus*), dominate. Hunters made use of dogs and trained birds of prey, and remains of the latter are found occasionally. A typical example of noble falconry is found at the Valkhof (*valk* being the Dutch word for falcon) in The Hague (Pavlovic & Nieweg 2006).

Typical noble dishes were copious and consisted of diverse and often rare luxury products. The species diversity, especially that of birds, is enormous (Supplementary Table 8). Some of these animals are rare, including turkey (*Meleagris gallopavo*) and Eurasian bittern (*Botaurus stellaris*). Banquets were decorated with swans, herons, storks, cranes and other large birds. Sea fish found on inland sites can also be considered high-status food (Supplementary Table 9). Even more rare are finds of large marine mammals, such as killer whale (*Orcinus orca*) at Velsen (Zeiler & Kompanje 2010) and North Atlantic right whale (*Eubalaena glacialis*) (Esser, Kootker & van der Sluis 2014; de Jong 2010) at both coastal and inland sites.

A variety of meat, poultry and fish was eaten at monasteries as well. Cattle is again dominant, except for the Carolingian and Ottonian period monastery in Susteren, where pigs dominate (Esser & van Hees in press). Clergy probably rarely engaged in hunting. Large wild mammals (both terrestrial and aquatic) are rare, and the few accounts of deer consist (with some exceptions) of the meatless parts. Common however, was the consumption of hare and rabbit (Supplementary Table 10).

A remarkable hunt-related find group is the hunting birds and (hunted?) crows at Ursulaklooster in Delft (van der Jagt 2017a). The diversity in domestic birds and wild ducks, geese and swans equals that at the castle sites, but that of other bird groups is lower (Supplementary

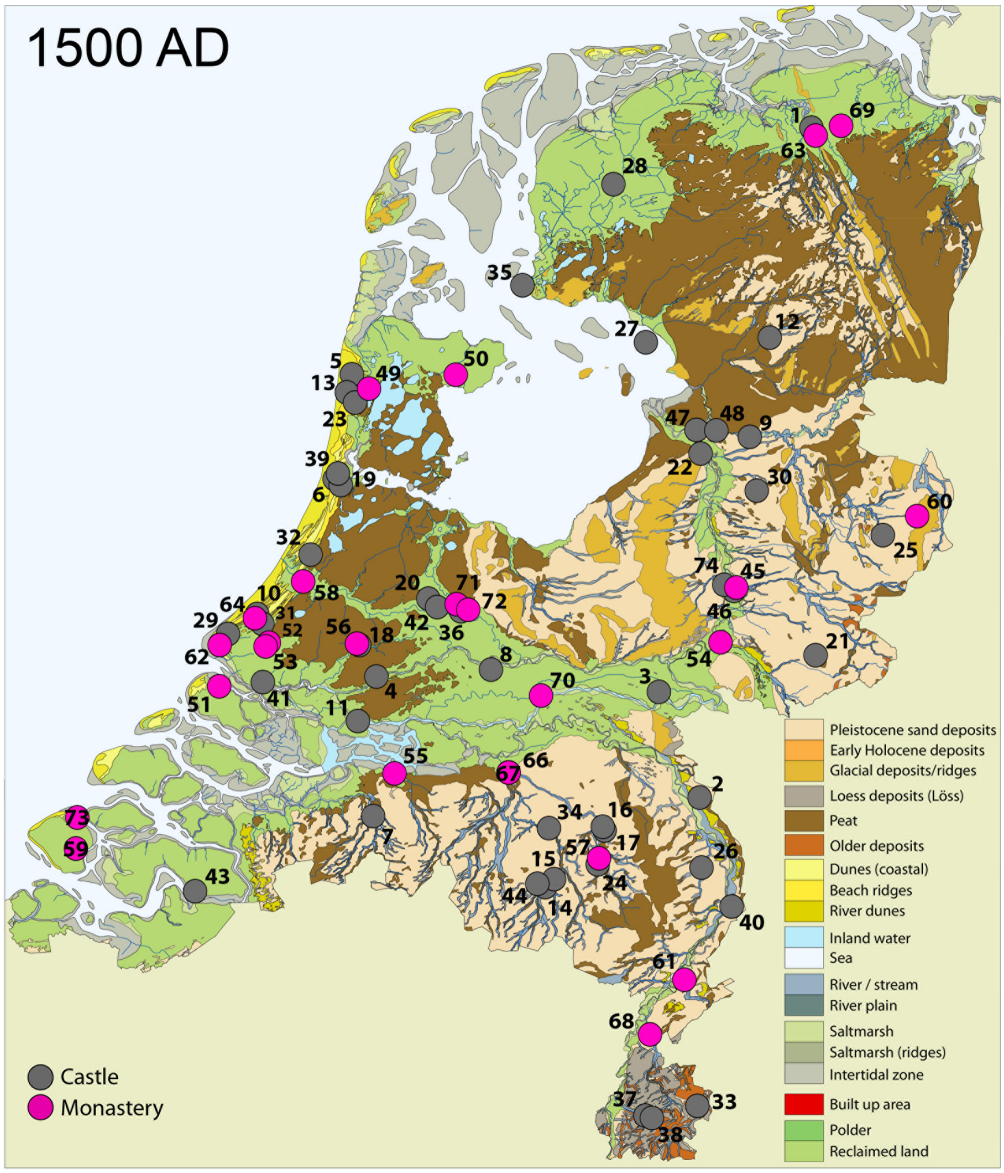

Figure 12: Map with castle and monastery sites discussed in the text and tables.

Table 11). Fish consumption is often related to monasteries; historical documents suggest that fish was frequently consumed during fasting. The number of fish taxa in monasteries is surprisingly similar to that found in castles (Supplementary Table 12), but the amount of fish consumed at monasteries is unknown.

Animals in Ritual: A Focus on Special Deposits

This section gives a chronological overview of known animal burials and other special animal deposits in the Netherlands, often referred to as ritual deposits. For the purposes of this discussion, we will keep the criteria for recognizing rituals broad and inclusive (see Groot 2008: 115–117).

Between the Late Palaeolithic and the Roman period, ritually deposited remains of diverse species are found in peat soils and stream valleys (Supplementary Table 13; **Figure 3, 7** and **11**). These off-site finds highlight the special significance of the landscape to prehistoric societies.

Special animal deposits from other contexts are scarcer dating from the Palaeolithic to the Bronze Age than they are in the later periods. Three 'ritually deposited' aurochs skulls from Almere, 5300–4200 BC (Peeters & Hogestijn 2001) and antlers and bones of red deer deposited with wooden sticks in pits at Hardinxveld-Giessendam, 5000–4600 BC, are among the better-known of such prehistoric finds (Louwe Kooijmans & Nokkert 2001). There are only a few accounts of animals in human graves: a complete cattle skeleton next to Late Neolithic graves at Garderen (2600–2500 BC), a cattle skull in a grave from Emst (2600–2500 BC), a presumable cattle skull from a Corded Ware culture grave from Zeijen (2850–2450 BC) (Behrens 1964, Louwe Kooijmans 1974: 323), and two cremated dogs in urns in a Middle Bronze Age burial mound at Borger (Prummel 2006a).

Animals played an important role in the burial tradition of the Iron Age and Roman period in the Netherlands. Meat portions were placed in inhumation graves (Lauwerier 2013) or burned with the body on the funeral pyre. Sometimes unburned portions were added to cremations. Studies of animal remains from cemeteries show a clear selection (Supplementary Table 14). Pig and sheep

or goat are most commonly found in burials, followed by chicken, which is only found in Roman cemeteries. Apart from animal remains included within graves, separate animal burials (three horses and one calf) were found in cemeteries in Valkenburg, Tiel and Zaltbommel, respectively (Verhagen 1987, Groot 2008: 178, Esser, van Dijk & Groot 2010). Animals were also part of rituals in Roman temples (Supplementary Table 15) (for a summary, see Groot 2016: 167–174) and were used in rituals that took place within settlements or fields. A range of deposits, from skulls and lower limbs to burials of complete animals, mostly dating to the Roman period, were found (see Groot 2009 for details). These comprise cattle, sheep, horse, dog, piglet, red deer and crow, and were found in relation to farmhouses, in or very close to enclosure ditches, in ditches of field systems, and in wells (van Giffen 1963: 246–248; van Londen 2006; Groot, 2009; van Haasteren & Groot 2013). These animals were probably offered for a variety of purposes.

Special depositions of animals or animal remains in the early Middle Ages are mainly found in extramural cemeteries or in burials situated within settlements. In a departure from previous periods, these concern mostly horses and dogs (Supplementary Table 16) (van der Jagt et al. 2014). The connection with animals in the early medieval burial rituals is also evident from the many finds of animal remains as additional gifts in the form of objects, such as pendants made of teeth of bears, beaver, and deer, and food (Supplementary Table 17) (van der Jagt 2017b). Other special depositions are not well documented, with the exception of a few from the northern part of the Netherlands that were described by Thilderkvist (2013). There is not much written about animals in rituals in the late Middle Ages. Special depositions of animals, especially burials of partial or whole animals, however, are plentiful. They are mainly found near farmsteads and are often interpreted as non-ritual. Establishing to what extent this interpretation is correct will require further study.

The Persistence of Fishing and Hunting through the Ages

Hunting and fishing continued to be practiced in some regions and periods even after the introduction of animal husbandry. How important were wild resources for subsistence or for other reasons, for example to express social differentiation or as a pastime? These questions are discussed for some large game species, birds, fish and cetaceans for the Mesolithic to the Middle Ages.

1. *Prehistory*

As mentioned above, hunting and fishing remained a key activity throughout the Neolithic, with Ewijk as the only exception dating prior to 4000 BC (Bakels & Zeiler 2005). In the central rivers area and along the west coast, wild boar and red deer, as well as otter, beaver, ducks, geese and swans, were hunted most frequently during both the Mesolithic and the Neolithic. Locally, where the landscape was more open (or became so as a result of human activities), roe deer was an important hunted species. Other large game species, such as aurochs, horse and elk (*Alces alces*), were also hunted, but in far lower numbers, most probably because their populations were small. The same goes for brown bear (*Ursus arctos*), marten (*Martes* sp.), polecat (*Mustela putorius*) and other fur-bearing animals (Prummel 1987c; Gehasse 1995; Zeiler 1997b; Zeiler 2006). In the Late Neolithic, wild mammals seem to have been hunted less frequently. On just one occasion, at the site of Mienakker, have large numbers of seal bones been unearthed (Zeiler & Brinkhuizen 2013).

The shift towards a primarily agricultural subsistence at the start of the Bronze Age, when '…people started […] living with their backs to nature…' (Louwe Kooijmans 1993: 80) will have caused wildlife exploitation to become increasingly less important (see **Figures 13–16** for selected taxa). This shift is demonstrated by the decreasing number of sites yielding wild boar, beaver and bird remains compared with the increasing number of sites with pigs and dogs (**Figure 13**). However, recent research at several

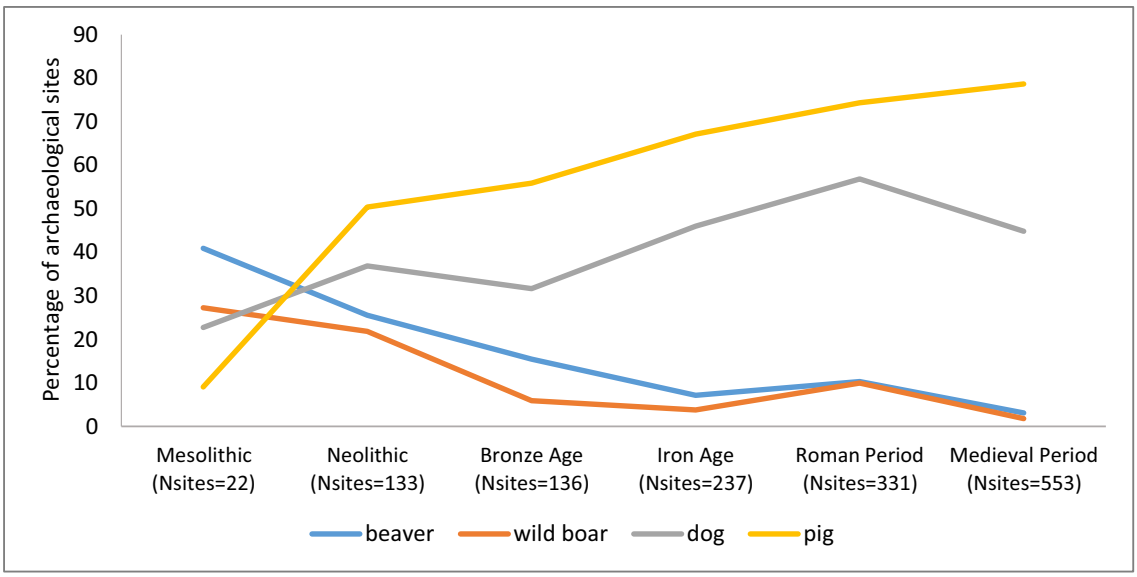

Figure 13: Percentages of archaeological sites in the Netherlands where remains of Eurasian beaver, wild boar, domesticated pig, and dog have been found, based on the online database 'BoneInfo' (RCE 2018).

West Frisian Bronze Age sites has shown that a wide range of habitats were still exploited, but likely through a more passive and concentrated form of hunting and fishing, e.g. by using traps during specific times of the year (van Amerongen 2014).

2. *The Roman and medieval periods*

Despite the increasing symbolic importance of wild mammals and birds in the Roman period, hunted mammals and birds were of minor importance as a source of meat (Lauwerier 1988). In her study of the Dutch rivers area, Groot (2016) shows this to be true at both producer (rural) and consumer (urban and military) sites. Military sites show a higher percentage of wild mammals than urban sites (Groot 2016: 178). The increase in wild mammals mainly occurred in the Late Roman period (Lauwerier 1988; Groot 2008). This may be related to a decline in population and a regeneration of woodland (Bakels 1996; Lauwerier 1988).

During the (late) medieval period, hunting became a pastime of the aristocracy, who owned the land and allocated the hunting rights (den Hartog 2005). This way, hunting became unavailable to the largest part of society. Fishing, however, became significantly more important during the late medieval period. The rise of in particular marine fish exploitation in this era (**Figure 14**) can be attributed to rapid developments in maritime technology and fish conservation techniques (e.g. Hoffmann 2005), together with the increasing demand for fish that accompanied the re-establishment of urban centres and associated population growth from the 12th century onwards (van Houtte 1977).

3. Birds

In the coastal areas, fowling was practiced on a larger scale than at inland sites (Zeiler & Clason 1993). This may simply be a consequence of the ecological potential of these habitats: in tidal areas, birds tend to gather in large numbers because of the presence of rich food sources. Fowling was of great interest during the Mesolithic and Neolithic, but of little interest during the Bronze and Iron Ages. It became more important again in the Roman and the medieval periods (**Figure 15**). Ducks, geese and

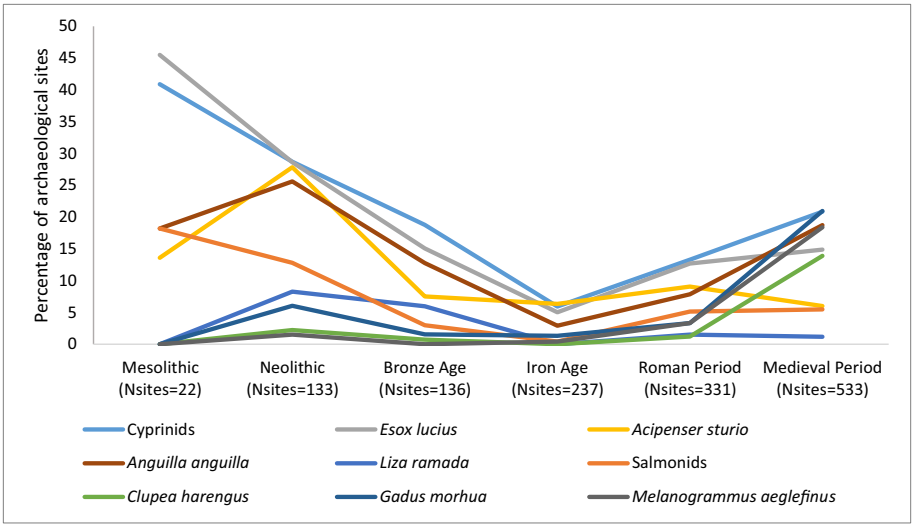

Figure 14: Percentages of archaeological sites in the Netherlands where remains of selected freshwater, marine and migratory fish taxa have been found, based on the online database 'BoneInfo' (RCE 2018).

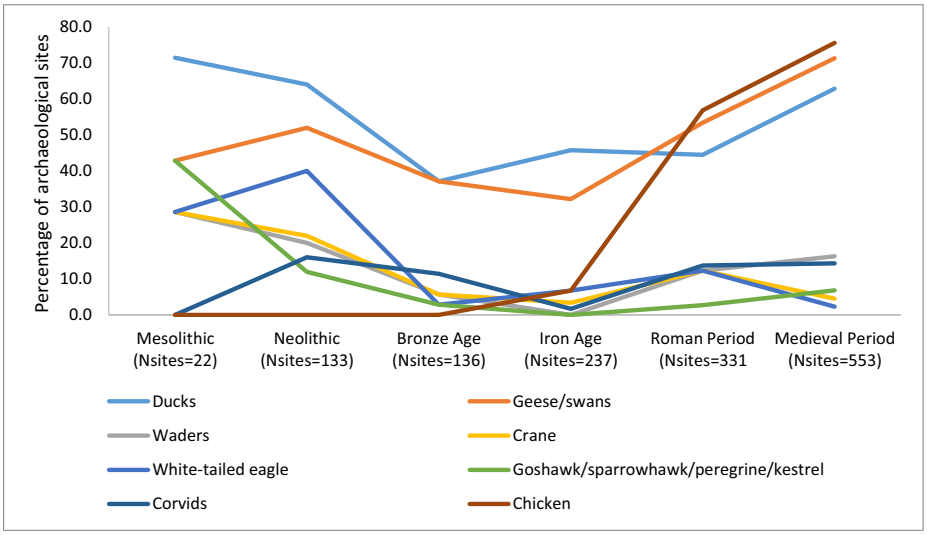

Figure 15: Percentages of archaeological sites in the Netherlands where remains of bird (Aves) or selected (groups of) bird species have been found, based on the online database 'BoneInfo' (RCE 2018).

swans were the most often fowled birds in all periods. It must be noted, however, that, by the medieval period, these three taxonomic groups include the remains of domestic ducks (*Anas platyrhynchos domesticus*) and geese (*Anser anser domesticus*), which could not always be distinguished from those of their wild relatives. In order to illustrate the medieval upsurge of domestic fowl, the proportions of sites that include the remains of chicken (introduced in the Netherlands during the Roman period) are shown as well. White-tailed eagle (*Haliaeetus albicilla*) and crane (*Grus grus*) were hunted quite often during the Mesolithic, the Neolithic and the Roman period. Goshawk (*Accipiter gentilis*) and sparrowhawk (*Accipiter nisus*) were hunted during the Mesolithic and Neolithic in small numbers. Their bones and those of peregrine (*Falco peregrinus*) and common kestrel (*Falco tinnunculus*) are rather common at late medieval elite sites, suggesting that they belonged to hawks, which were trained birds of prey. The increase in the proportions of waders and corvids during the medieval period can be partly explained by the fact that they (and ducks, geese and many other species) are among the quarry of hawks (Prummel 2013; Prummel 2018).

4. Cetaceans

Cetacean remains are common in Late Neolithic, Roman and medieval sites (**Figure 16**) (van den Hurk 2014). Medieval sources mentioning cetacean exploitation for the Netherlands are rare, but sources from Flanders, France and England suggest that hunting was occasionally undertaken, that the meat was highly prized, and that especially porpoise meat was seen as a delicacy (De Smet 1981). Hunting for cetaceans may therefore also have occurred in the Netherlands during the medieval period, as their remains are frequently encountered in ecclesiastical and high-status sites. The majority of the exploited cetaceans, however, probably derive from stranded individuals (Speller et al. 2016).

The Use of Isotopes in Dutch Archaeozoological Research

During the past decade, the use of isotope geochemistry in Dutch human and faunal osteoarchaeological research has shifted from sporadic application to systematic integration. In particular strontium (Sr) and oxygen (O) isotopes have proven their value in enabling researchers to deduce the geographical catchment area where inhabitants and animals of the archaeological settlements originated, as specific $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ values refer to specific geological and geographical locations, respectively. Moreover, carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) isotopes are often applied to monitor the individual dietary aspects of human and animals, which can also assist as indicators for mobility and to gain insight into animal husbandry. Hence, multidisciplinary studies of sites from all archaeological periods provide the opportunity to study the provenance of humans and animals, the age at which mobility took place, the dietary aspects of life, and, most importantly, how they were related, in order to provide a better understanding of the social-economic influences of migration, dietary change, trade, exchange and animal husbandry. Although most isotopic work in the Netherlands has focussed on human individuals (see Kootker & Davies 2017 for an overview), isotopic analysis has become a staple component of archaeozoological research as well.

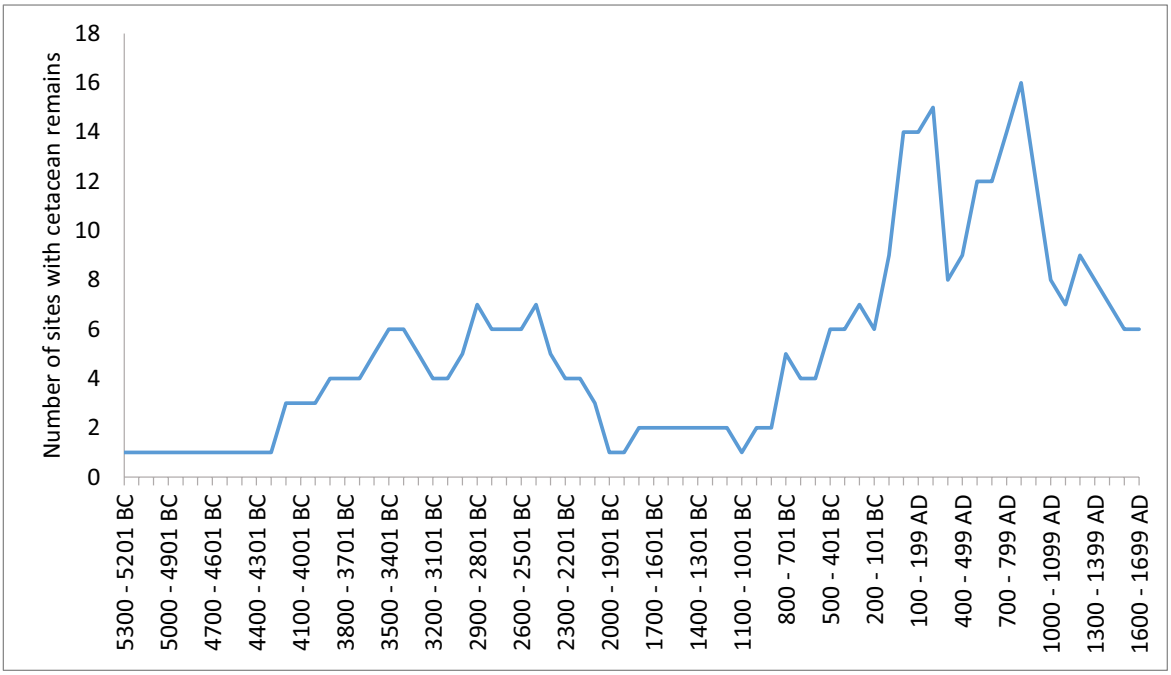

Figure 16: Number of sites with cetacean remains present within their archaeozoological assemblages per 100 year period (n = 60), based on the online database 'BoneInfo' (RCE 2018). Identified species are harbour porpoise (*Phocoena phocoena*), common bottlenose dolphin (*Tursiops truncatus*), killer whale (*Orcinus orca*), Atlantic right whale (*Eubalaena glacialis*), and sperm whale (*Physeter macrocephalus*). Most cetacean bones remain unidentified below the taxonomic level of family, a major problem in cetacean research in archaeozoology (Speller et al. 2016).

The first bioavailable strontium isotope distribution map of the Netherlands is solely based on archaeological rodents and carefully selected remains of archaeological medium-size mammals (such as foxes (*Vulpes vulpes*): Kootker et al. 2016). The map provides a first insight into the distribution of the $^{87}Sr/^{86}Sr$ ratios in the Netherlands and has become an essential component for the interpretation of archaeological strontium isotopic data. During the past few years, strontium isotope research has been conducted on a vast variety of animal species from archaeological contexts, including cattle, horse, sheep/goat, pig, wolf (*Canis lupus*), lynx (*Lynx lynx*), cat, and dog, dating to multiple archaeological periods. The obtained isotopic data show that cattle, horses, sheep/goat and pigs were subject to trade, exchange and long-distance mobility from as early as the Bronze Age (2000–800 BC) onwards (see e.g. Brusgaard 2014 (Bronze Age); Kootker et al. 2018 (Iron Age); van der Jagt et al. 2012 (Early Medieval); Esser, Kootker & van der Sluis 2014 (Modern era)).

In addition, baseline data for carbon and nitrogen isotope research heavily depends on the analysis of archaeological animal remains as well. Archaeological background species from three biological classes, mammals (e.g., cattle, pigs, sheep/goat), birds (e.g., duck, chicken), and fish (e.g., haddock (*Melanogrammus aeglefinus*), cod (*Gadus morhua*)), have been analysed. Research executed to date provides invaluable information about animal husbandry techniques. Pig isotopic data from Esser et al. (2014), for instance, are suggestive of landscape- and possibly household-dependent management, resulting in a variety of diets, ranging from purely herbivorous to omnivorous foods. Similar research carried out on medieval sheep/goat and cattle remains from the Groningen area in northern Netherlands points toward a grazing system in which the more salt-tolerant sheep were kept on the saline thrifts and cattle were kept on grasslands, farther away from the coast; a system that remained in use for at least a few hundred years (late medieval to modern era, Kootker et al. 2016).

In conclusion, the application of several isotope systems in Dutch archaeozoological research has proven its potential. We are able to collect more knowledge about provenance and mobility patterns of animals and gain valuable information about animal husbandry practises. The incorporation of isotope geochemistry in commercial faunal osteoarchaeological research, however, is still subject to improvement. Future isotopic work will undoubtedly contribute significantly to our understanding of the past human–animal relationships.

Extirpations and introductions

The Dutch Holocene vertebrate faunal record shows many changes due to human-mediated extirpations and introductions of other species (**Figure 17**). Knowing which species became extirpated, which species were introduced, as well as how and when, is crucial to inform present-day conservation management. While some of the extirpations and introductions have similar timelines and causes as those in the rest of northwestern Europe, others are specific for the Netherlands. Habitat change, mostly induced by the introduction of domestic fauna and arable farming, is the most important cause of the extirpation of wild fauna.

Wild horse seems to have been present in small numbers in the Netherlands until at least the 5th millennium BC, but probably even later into the Neolithic (Laarman 2001; Zeiler 1997b; Zeiler & Brinkhuizen 2015). Aurochs survived until about AD 600 on the northern salt marshes, despite having been surrounded by large populations of domestic cattle (Prummel & Olivier 2008; Thilderkvist 2013: 58–59). Elk survived in the central part of the country until the 11th–13th centuries AD (Esser 2000;

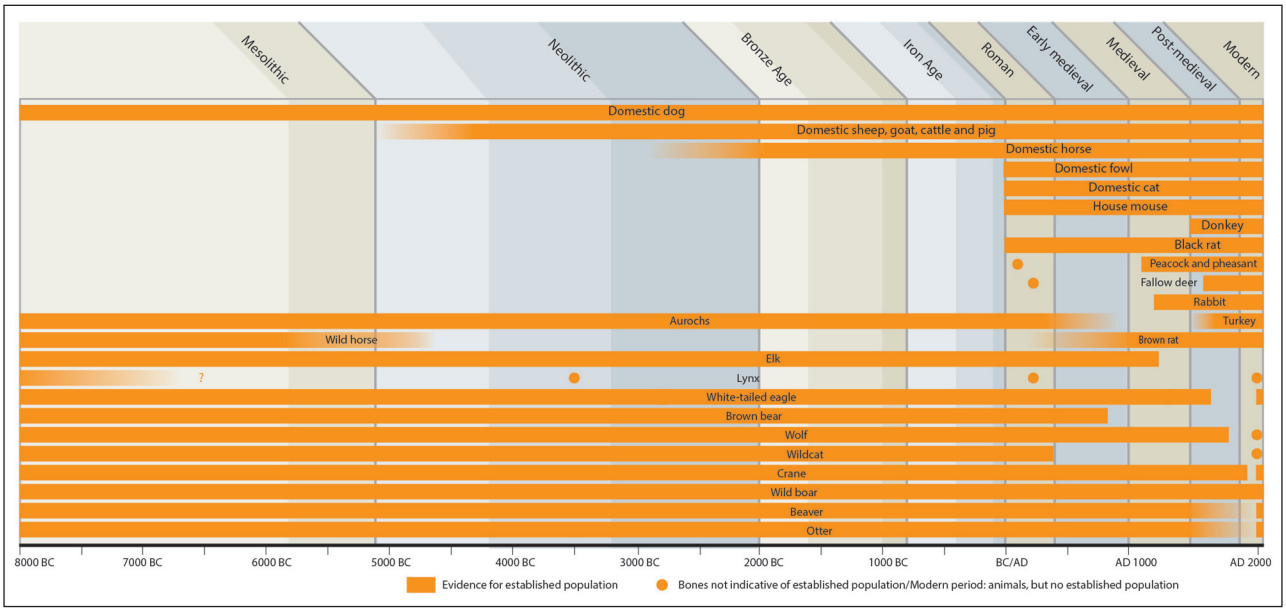

Figure 17: Overview of introductions and extinctions of some mammal and bird species in the Netherlands during the Holocene, based on the online database 'BoneInfo' (RCE 2018) and references mentioned in the section 'Extirpations and introductions'. Figure adapted from (Baker & Worley 2019, Fig. 1.2).

Buitenhuis & Brinkhuizen 2003). The brown bear disappeared from the Netherlands ca. AD 1000. A partial brown bear skeleton found in the dunes near Noordwijk in 2016 is dated 880–970 cal AD (Kuijper et al. 2016). Little is known about the presence of lynx in the Netherlands, and hardly any lynx bones have been found. Vagrant lynxes have, however, occasionally been encountered in the southern-most part of the Netherlands since AD 2000 (Mulder 2016a; Bakker 2018).

Other extirpations, especially of aquatic fauna, are directly related to overexploitation and habitat destruction. Beaver had become extinct by 1826; the last was killed at Zalk, along the River IJssel. This species was successfully reintroduced from the River Elbe in 1988 (Sluiter 2003; Dijkstra 2016). The otter had a similar history, with, in this case, a 20th century extirpation and a reintroduction in 2002–2008 (Lammertsma et al. 2008; Lammertsma & Niewold 2016). Waterworks and pollution have had a negative effect on Dutch fish populations and have heavily affected the occurrence of species, such as the Atlantic salmon (*Salmo salar*) (Lenders et al. 2016).

The increased human habitation of the wetlands had a negative effect on the bird population. White-tailed eagle, crane, and the grey-lag goose (*Anser anser*) ceased breeding in the Netherlands in the post-medieval period. Thanks to protection and habitat recovery since the last decades of the 20th century, these species have once again become breeding birds of the Netherlands (van Straalen 2018; Feenstra 2018; Voslamber & Koffijberg 2018).

A number of species are difficult to trace in the archaeozoological record, either because humans did not hunt the species or because they did not bring the skeletons to their settlement. Wolf is a good example. The few archaeozoological records of wolves shed no light on the population dynamics of this species in the past. A small number of wolves have been observed in the southern part of the Netherlands in the 19th century. Several incidental appearances of wolves originating from lowland Germany have been recorded since 2015. They made wildlife managers and the public question whether the wolf is returning to the Netherlands. The latest information indeed suggests that this is the case (Lelieveld et al. 2016; La Haye & Verboom 2017). The wild cat (*Felis sylvestris*) disappeared from the country during the Roman period, but returned to the south-eastern part of the country in 2012 (Mulder 2016b; Kuipers 2017).

Many introduced species are domesticated. Domestic cat and chicken, which were introduced elsewhere in Europe during the Iron Age (but remained rare until the Roman period), are absent in the Dutch archaeological record of the Iron Age. Domestic cat was introduced in the Netherlands in the Early (12 BC–AD 70) or Middle Roman period (AD 70–270). Domestic chicken, which was introduced to Europe as an 'exotic' species during the Iron Age and was mainly used in burials during this period, assumed economic importance much later in the Roman period (Sykes 2012). Chicken appears in the Dutch record in the Early Roman period (the first finds are from the Roman Castellum Velsen 1, AD 15–30 Prummel 1987d).

It is interesting that some of the domestic animals that are associated elsewhere with Romanisation were not introduced to the Netherlands until early Modern times. Although an implement made of a fallow deer (*Dama dama*) metatarsus has been found in the Roman Castellum Valkenburg (Prummel 1977), there is no indication of any fallow deer population in the Netherlands during the Roman period. The first historical record of fallow deer in deer parks of an aristocratic class dates to AD 1516 (Litjens & Pelzers 1988). This is in contrast with Britain, where enclosed fallow deer populations are known to have been established by the Romans (Sykes et al. 2011).

A peacock (*Pavo cristatus*) bone discovered in the Roman Castellum Velsen 1 (Prummel 1987) may come from a single import of peacock meat. The peacock bones found at some late medieval elite sites definitely come from peacocks living at those sites. The earliest late medieval archaeozoological peacock find is from Helmond (AD 1170–1400, de Jong 1992).

Other introductions in the late Middle Ages include rabbit, pheasant and common carp (*Cyprinus carpio*). Rabbits appear in the Dutch historical record in AD 1297, when they were introduced as game, at first within enclosures. After they escaped, they had devastating effects on the landscape (van Dam 2001, Lauwerier & Zeiler 2001). The pheasant was introduced as game; the first archaeozoological record is from Maastricht, AD 1250–1350 (BoneInfo Cluster 259) (Hiddingh 1983, Lauwerier 1997). The first carp was introduced as lent food; the first archaeozoological record is from Zutphen, AD 1125–1175 (Beerenhout 2011b).

Domestic duck and goose seem to have been introduced during the late Middle Ages, a conclusion that is based on the dramatic increase in duck and goose bones in the archaeozoological record of the Netherlands and the increase in the prevalence of large individuals. See the section on the persistence of fishing and hunting. Whether and how much the Dutch wild populations contributed to their domestication remains a question. After all, the word decoy derives from the Dutch word *eendenkooi*, referring to the combination of a pond, screens, nets a dog and domestic ducks to capture wild ducks.

Introductions from the Americas are also reflected in the archaeological record. Turkey (*Meleagris gallopavo*) was introduced soon after AD 1492; the first records are from Breda (AD 1530–1540, De Jong, Carmiggelt & van den Eynde 1997) and Alkmaar (AD 1475–1550 and AD 1450–1600, van Haaster, Zeiler & Brinkhuizen 2012). Exotic species like the raccoon (*Procyon lotor*), raccoon dog (*Nyctereutes procyonoides*), muskrat (*Ondatra zibethicus*), and American mink (*Neovison vison*) have made their way into the Netherlands even more recently, often bringing harm to the populations of native species.

The Archaeozoology of the Terp Area

Between 2000 and 650 BC, tidal flats and salt marshes developed between the Pleistocene sandy soils in the north of the Netherlands and the islands along the coast (in the Provinces of Friesland and Groningen) (**Figure 18**). Settlers came to live here ca. 600 BC and built dwelling mounds (terps) on the salt marsh to be safe at high water

(Vos & Knol 2015: 211). Fresh clay was deposited during flood inundations, which made the salt marsh very fertile. It is commonly accepted that bones and shells preserve exceptionally well in terp soil. The rich archaeozoological record of the unique terp phenomenon has fascinated archaeozoologists since the time of van Giffen, the founder of Dutch archaeology. Subsistence in the unembanked salt marsh and tidal flat areas in this part of the Netherlands must have been quite different than elsewhere in the Netherlands or Europe in general, at least until the first dykes were built around AD 1200.

The first dwellers, of the Iron Age, had a strong preference for cattle husbandry (Supplementary Table 18, **Figure 19**). Sheep husbandry became more important

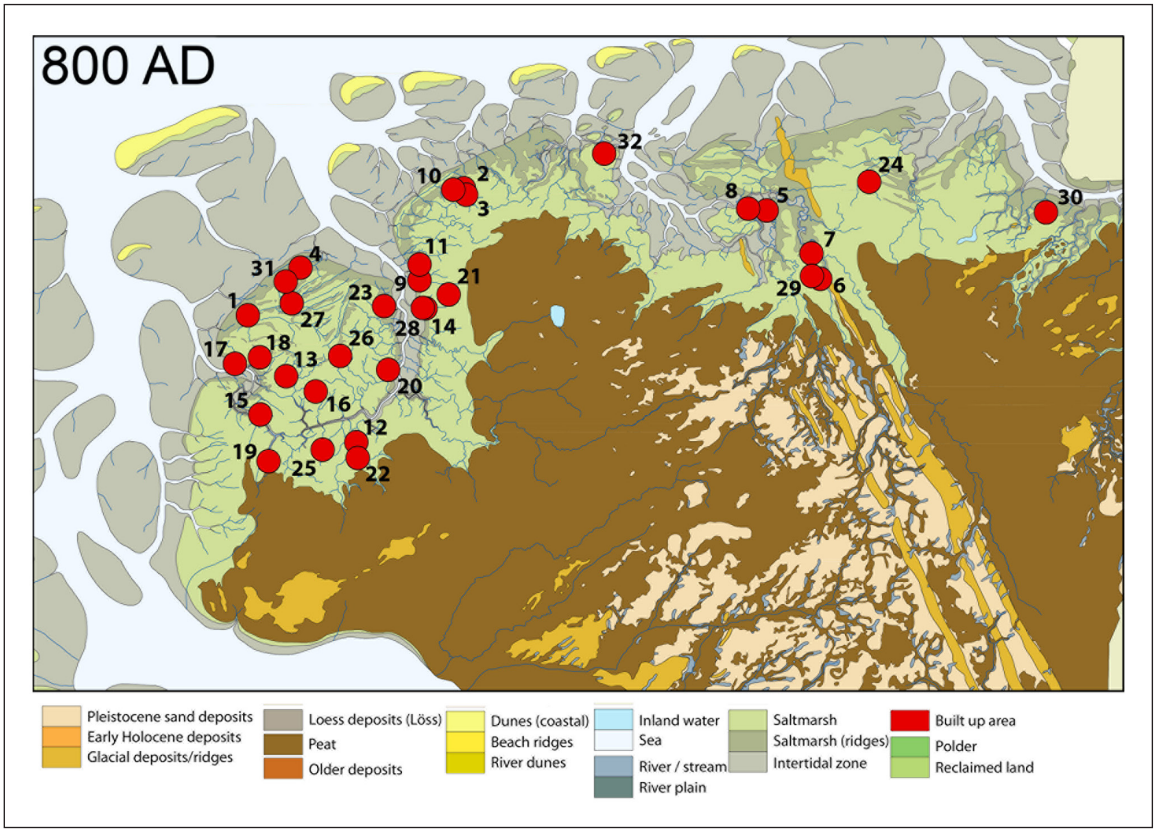

Figure 18: Map with terp sites discussed in text.

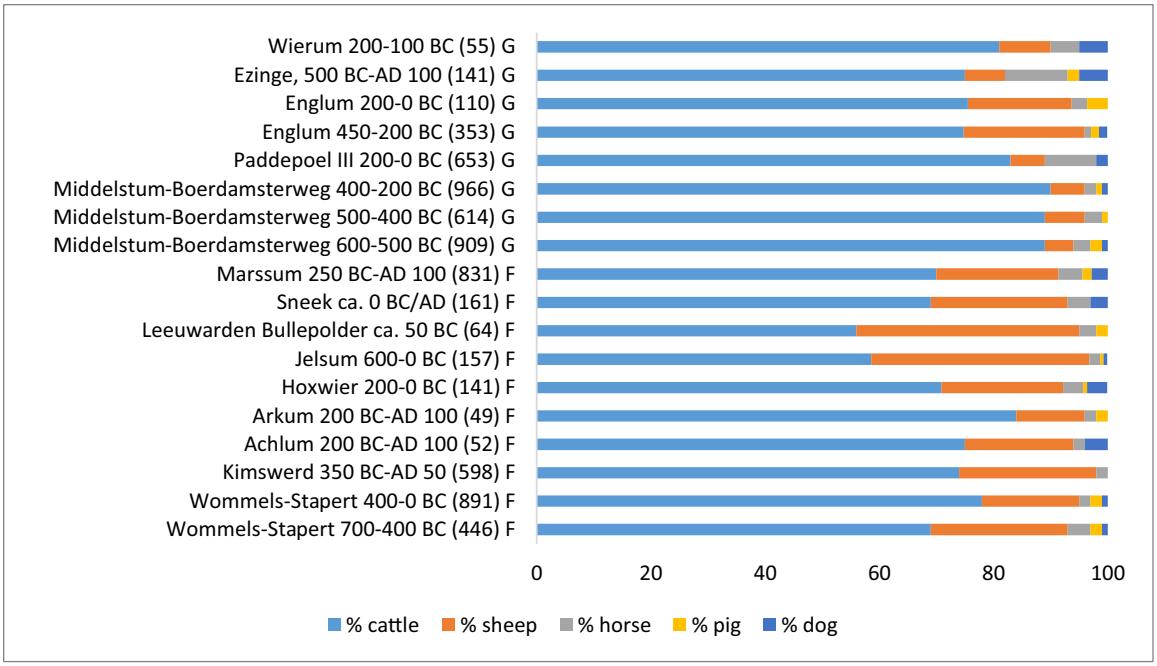

Figure 19: Percentages of cattle, sheep, horse, pig and dog remains in selected Iron Age terp sites. Site, time period, (NISP), (G): Groningen, (F): Friesland.

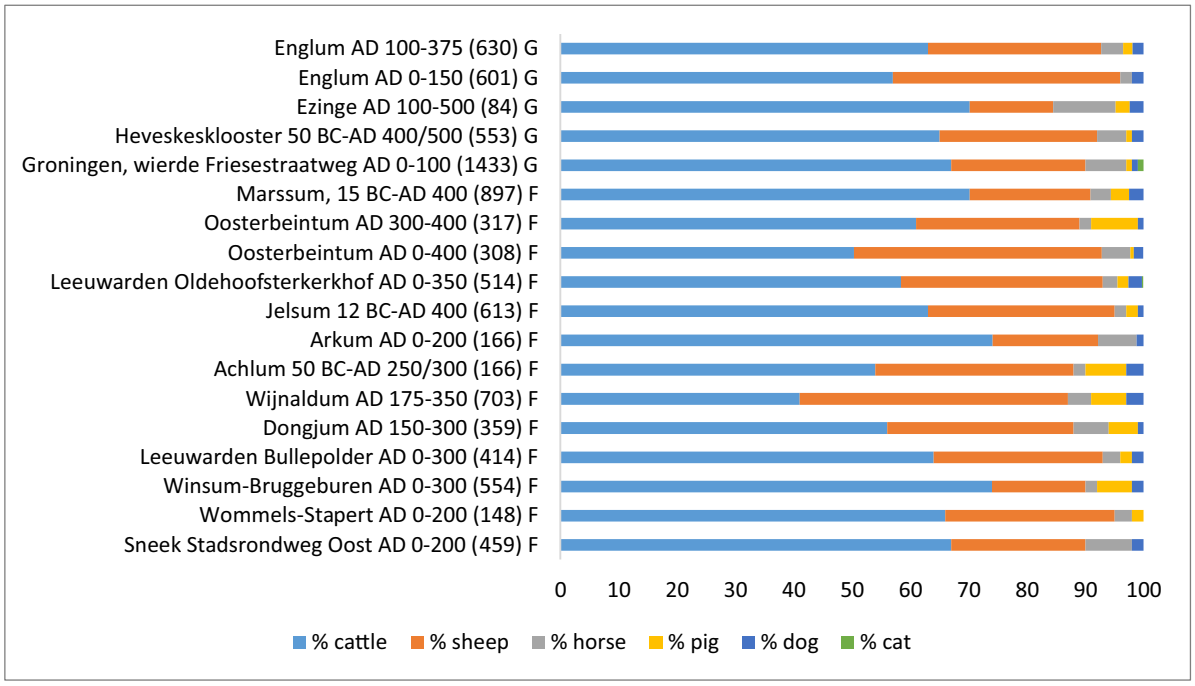

Figure 20: Percentages of cattle, sheep, horse, pig and dog remains in selected Roman period terp sites. Site, time period, (NISP), (G): Groningen, (F): Friesland.

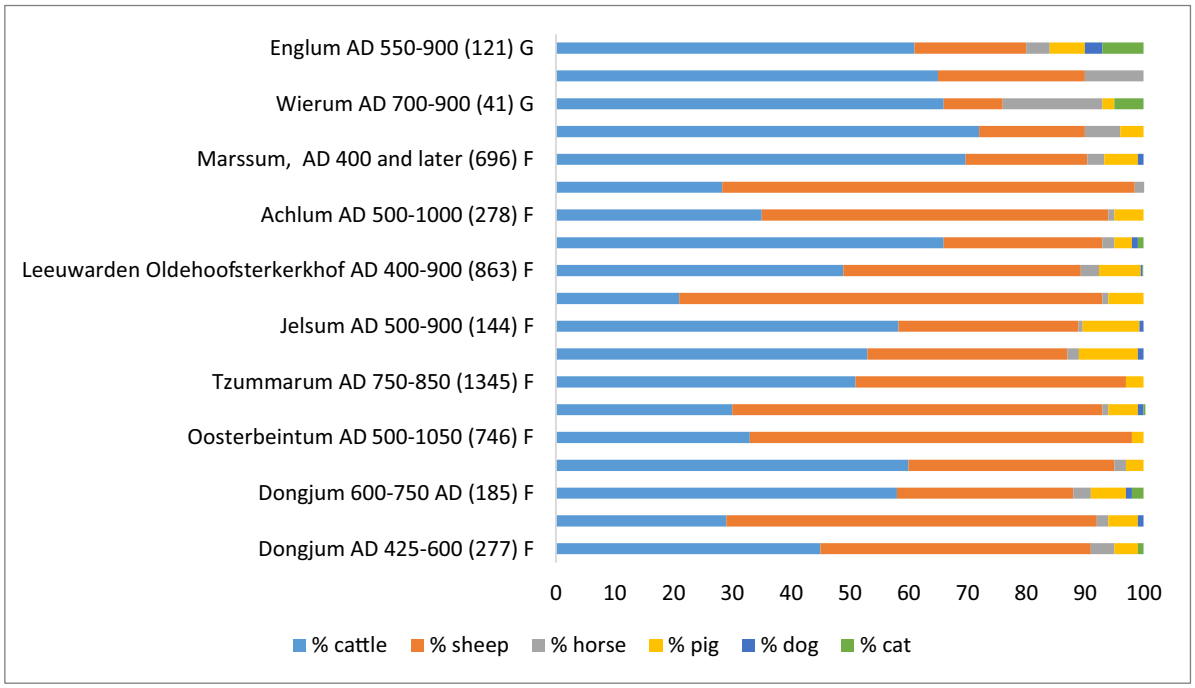

Figure 21: Percentages of cattle, sheep, horse, pig, dog and cat remains in selected early medieval terp sites. Site, time period, (NISP), (G): Groningen, (F): Friesland.

during the Roman period (Supplementary Table 19, **Figure 20**) and even more during the early Middle Ages (Supplementary Table 20, **Figure 21**). The increase in sheep husbandry was probably related to wool becoming a trading commodity. The Roman army had a large demand for wool. The area was part of an extensive trading system along the North Sea during the early Middle Ages, with woolen textile as an important commodity (Prummel 2014).

Sheep husbandry seems to have been more important at terps in Friesland than at those in Groningen, probably thanks to the influence of marine conditions in Friesland creating suitable meadows for sheep herds (Prummel 2006b: 42–45, Prummel, Esser & Zeiler 2013; Prummel 2014, Hullegie & Prummel 2015: 151–153).

Hunting was practiced on a limited scale on the terps. Fowling and fishing were hardly practiced during the Iron Age, but they were of some importance during the Roman

and early medieval periods, especially at terps near the coast and at what are argued to be elite terps (Prummel, Esser & Zeiler 2013; Zeiler 2014; Timmerman 2012). Ducks, geese and wading birds were the most important game, and flatfishes and eel (*Anguilla anguilla*) the most captured fish species. Marine molluscs were consumed at most terps. Bones of stranded large whales were sometimes collected to use the oil or the bones (Prummel, van Gent & Kompanje 2012).

Between AD 1200 and 1300, most of the salt marshes were embanked, bringing an end to this unique way of life in the northern parts of the Netherlands (Vos & Knol 2015: 215).

Conclusions

Thousands of archaeozoological assemblages have been analysed in the Netherlands since Clason published her dissertation in the 1960s, immensely enriching our understanding of past human–animal interactions. The number of archaeozoologists and the amount of archaeozoological data in the Netherlands are growing steadily. An increase in the employment of molecular techniques (stable isotope analysis, palaeogenetics, and ZooMS (zooarchaeology by mass spectrometry)) has begun to add a much-welcomed layer to the information that can be gained from conventional faunal analysis.

With the incorporation of data from molecular analyses, the data are becoming more solid and research questions are becoming more refined.

These are great developments in which we all participate and advocate for in governmental, academic and commercial institutions. However, assemblage-based research, regardless of the methods used to conduct it, continues to lead to knowledge fragmentation. The paper is also the result of an exercise in the re-use of (digital) archaeozoological data and in crowd-sourcing among archaeozoologists who operate primarily in the heritage sector. The BoneInfo database proved to be an excellent open-source starting point. However, quantitative meta-analysis had to depend for the most part on published reports, which was, as expected, time consuming. For more detailed and reproducible overviews and more interesting narratives of *Animals and People in the Netherlands*, interoperable data-sharing platforms are desirable.

Additional Files

The additional files for this article can be found as follows:

- **Supplementary Table 1.** Archaeological periods used in Dutch archaeology. The table gives the period codes used in the online database 'BoneInfo', the name of the period and the period in years; ages in 'C14' are uncalibrated dates BP; ages in 'BC' and 'AD' are calibrated dates. DOI: https://doi.org/10.5334/oq.61.s1
- **Supplementary Table 2.** Sites and assemblages used in **Figure 3**. DOI: https://doi.org/10.5334/oq.61.s1
- **Supplementary Table 3.** Zooarchaeological and site data used in **Figure 3**. DOI: https://doi.org/10.5334/oq.61.s1
- **Supplementary Table 4.** Ratio of cattle, sheep/goat and pig for Merovingian and Carolingian sites. Only sites with a NISP ≥ 100 of cattle, sheep/goat or pig (excluding associated bone groups) were used. * burnt remains. ** two exceptional pits filled with pig mandibles have been excluded from the NISP. DOI: https://doi.org/10.5334/oq.61.s1
- **Supplementary Table 5.** Overview of the excavated and archaeozoologically studied Dutch castle sites, including references. DOI: https://doi.org/10.5334/oq.61.s1
- **Supplementary Table 6.** Overview of the excavated and archaeozoologically studied Dutch monasteries, including references. DOI: https://doi.org/10.5334/oq.61.s1
- **Supplementary Table 7.** Mammal species found at castle sites in the Netherlands. DOI: https://doi.org/10.5334/oq.61.s1
- **Supplementary Table 8.** Bird species found at castle sites in the Netherlands. DOI: https://doi.org/10.5334/oq.61.s1
- **Supplementary Table 9.** Fish species found at castle sites in the Netherlands. DOI: https://doi.org/10.5334/oq.61.s1
- **Supplementary Table 10.** Mammal species found at monastery sites in the Netherlands. DOI: https://doi.org/10.5334/oq.61.s1
- **Supplementary Table 11.** Bird species found at monastery sites in the Netherlands. DOI: https://doi.org/10.5334/oq.61.s1
- **Supplementary Table 12.** Fish species found at monastery sites in the Netherlands. DOI: https://doi.org/10.5334/oq.61.s1
- **Supplementary Table 13.** Overview of animal species found in peat soils and stream valleys in the northern and southern Netherlands. 'X' denotes the presence of the species. DOI: https://doi.org/10.5334/oq.61.s1
- **Supplementary Table 14.** Number of bone fragments for temple sites for the pre-temple period (Late Iron Age/Early Roman period). Additional data from the Fortuna temple: four fragments of quail, one of herring (*Clupea harengus*), one of smelt (*Osmerus eperlanus*) and one of Cyprinidae. DOI: https://doi.org/10.5334/oq.61.s1
- **Supplementary Table 15.** Animal species found in Late Iron Age and Roman cremation cemeteries in the Netherlands. Only cemeteries with ≥5 graves with identified animal bones have been included. x: burned; +: unburned. LIA: Late Iron Age; ROM: Roman period. DOI: https://doi.org/10.5334/oq.61.s1
- **Supplementary Table 16.** Animal burials found in early medieval cemeteries. The numbers in parentheses are individuals of that are described as possible animal burials. (inh: inhumation; cr: cremation). DOI: https://doi.org/10.5334/oq.61.s1

Supplementary Table 17. Overview of animal remains in early medieval cemeteries, excluding animal burials and objects. Some of these remains are clearly food gifts, but others may not be. In Elst, the inhumation graves contained burnt animal remains. 'X' denotes the presence of the species, '(x)' denotes that bone

was found but it is not certain whether it is animal or human. DOI: https://doi.org/10.5334/oq.61.s1

- **Supplementary Table 18.** Percentages of cattle, sheep, horse, pig and dog remains from selected Iron Age terp sites. (h: hand collected, s: sieved). DOI: https://doi.org/10.5334/oq.61.s1
- **Supplementary Table 19.** Percentages of cattle, sheep, horse, pig and dog remains from selected Roman period terp sites. (h: hand collected, s: sieved). DOI: https://doi.org/10.5334/oq.61.s1
- **Supplementary Table 20.** Percentages of cattle, sheep, horse, pig, dog and cat remains from selected early medieval terp sites. (h: hand collected, s: sieved). DOI: https://doi.org/10.5334/oq.61.s1
- **Supplementary Table 21.** Site information for all the sites considered as part of this study. DOI: https://doi.org/10.5334/oq.61.s1
- **References for the Supplementary Tables.** References for the Supplementary Tables. DOI: https://doi.org/10.5334/oq.61.s2
- **Methods.** Methods used for the sections. DOI: https://doi.org/10.5334/oq.61.s3

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Competing Interests

The authors have no competing interests to declare.

Author Contributions

The archaeozoology of the Pleistocene: Thijs van Kolfschoten, Theo de Jong; The Mesolithic–Neolithic transition: Canan Çakirlar, Jørn Zeiler, Rianne Breider, Wietske Prummel; The subsistence economy of the metal ages: Joyce van Dijk, Yvonne van Amerongen; The Roman period: Maaike Groot, Roel Lauwerier; The size and shape of cattle and horse in the Roman period: Roel Lauwerier, Kinie Esser, Theo de Jong, Joyce van Dijk, Canan Çakirlar, Maaike Groot; The early medieval period: Kinie Esser; Animals in castles and monasteries: Inge van der Jagt, Kinie Esser; Animals in ritual: A focus on special deposits: Inge van der Jagt, Maaike Groot, Wietske Prummel; The persistence of fishing and hunting through the ages: Jørn Zeiler, Wietske Prummel, Joyce van Dijk, Jan Bakker, Youri van den Hurk; The use of isotopes in Dutch archaeozoological research: Lisette Kootker; Extirpations and introductions: Wietske Prummel, Thijs van Kolfschoten, Kinie Esser; The archaeozoology of the terp area: Wietske Prummel. Frits Steenhuisen and Youri van den Hurk created the maps. Canan Çakirlar, Youri van den Hurk, Inge van der Jagt, Thijs van Kolfschoten, Wietske Prummel, Roel Lauwerier designed the study, organized the work, wrote and edited the manuscript.

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