Livestock for sale: Animal Husbandry in a Roman Frontier Zone

THE CASE STUDY OF THE CIVITAS BATAVORUM

Maaike Groot

Amsterdam Archaeological Studies 24

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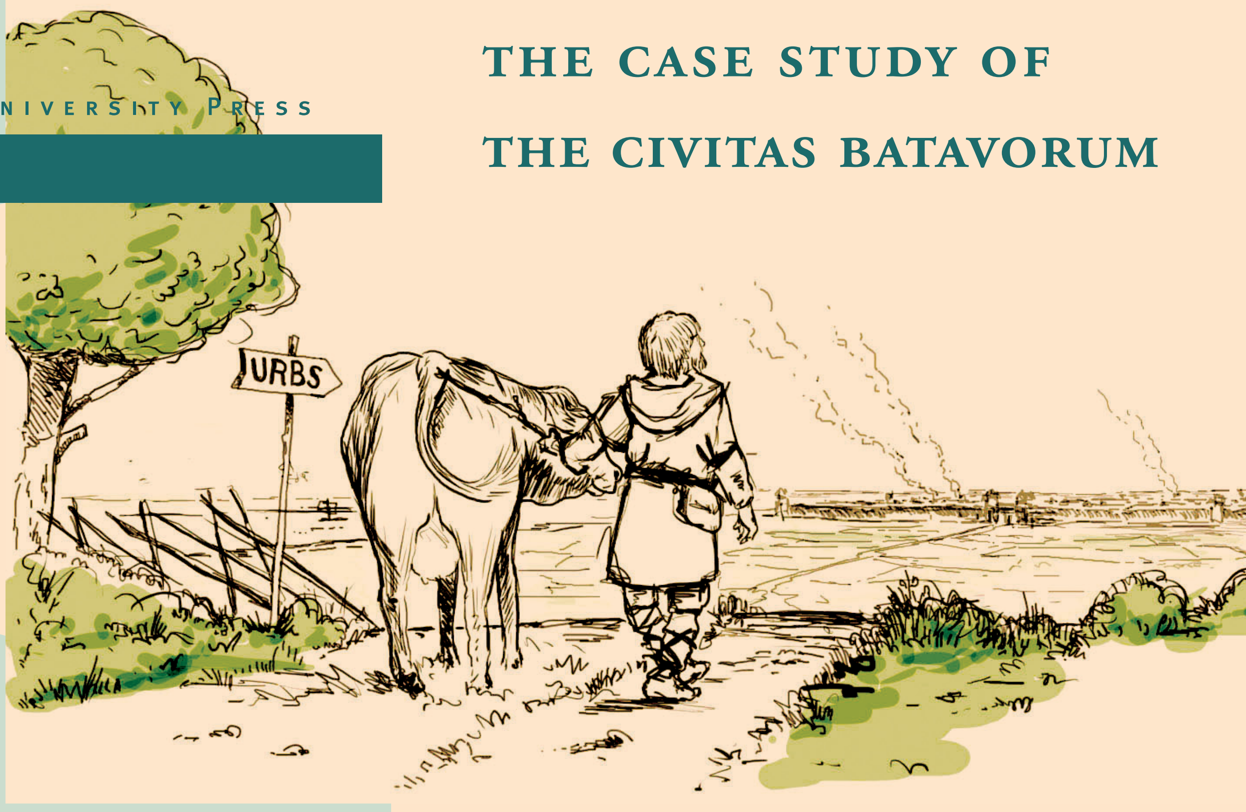

Livestock for Sale

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Below: A Batavian farmer taking his cow to market (Illustration: Mikko Kriek)

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FOREWORD

The idea of writing a synthesis of animal husbandry in the Roman Dutch River Area arose early in my research project *Livestock for sale: the effect of a market economy on rural communities in the Roman frontier zone*. At the time, it seemed a good idea, probably because I had no idea of the time and work that would be involved. As it turned out, time ran out in the first project and I needed a second research project in which to finish the manuscript (*Sustaining the Empire: farming and food supply in two Roman frontier regions*). Over five years later, the work is finally finished. I could not have written this book without the help of a number of colleagues, who I would like to thank here. My zooarchaeological colleagues, especially Joyce van Dijk, Kinie Esser, Frits Laarman and Bill Whittaker, provided primary data and unpublished reports. Sabine Deschler-Erb, Joyce van Dijk, Laura Kooistra and Nico Roymans commented on an earlier version of the manuscript, followed by two anonymous reviewers who also provided useful comments. Finally, I would like to thank the Netherlands Organisation for Scientific Research and the Gerda Henkel Foundation for financing the two research projects that led to this book.

EXTRA TABLES AND ILLUSTRATIONS

The number of tables and illustrations I originally included in the manuscript was too large for a printed book. I therefore selected those that were essential to the text; the others are preceded with an 'E' in references in the text, and can be accessed online: http://dx.doi.org/10.17026/dans-zth-dgam

1. Introduction

1.1 FRAMEWORK, SCOPE AND RESEARCH QUESTIONS

1.1.1 INTRODUCTION

Little is known about the way in which previously self-sufficient rural communities responded to market demand for agrarian products in the past, or about the resulting changes in agrarian strategies.

This topic will be studied through a case study of animal husbandry in the Lower Rhine area in the Roman period. With the arrival of the Romans to the southern and central part of what is now the Netherlands, a substantial group of consumers was introduced into what was basically a subsistent agrarian society. In earlier periods, with the exception of perhaps a small minority of religious or craft specialists, everyone was involved in agrarian production. The arrival of the Roman army constituted a large group of people that depended on others for their food. Moreover, in the town of Nijmegen, we find administrators, traders and craftsmen, most of whom did not or only to a limited extent produce their own food. The Roman occupation thus introduced a separation between producers and consumers.

The Roman army and administrators, as well as an influx of traders, stayed in the southern half of the Netherlands for nearly four centuries. While some products were imported, other foodstuffs were of local origin. The presence of imported material culture in rural sites is an indication that local people participated in trade. With farming as their economic basis, an agrarian surplus is the most likely form of goods that could be traded for imported products such as pottery. This means that the local farmers managed to produce more food than they needed for themselves. How they managed this is the main question of this study. The aim is to trace developments in animal husbandry from the Late Iron Age to the Late Roman period, investigate whether these developments can be related to market demands, and gain an understanding of the impact of the Roman occupation on the agrarian economy.

Although this is a case study, it is expected that the results will be of wider relevance to other researchers with an interest in agrarian societies faced with major economic changes or in the organisation of food supply to towns and army.

1.1.2 RESEARCH AREA AND TIME FRAME

This study focuses on the Roman period (12 B.C. – A.D. 350) in the Dutch River Area (fig. 1.1). This region not only covers a distinct geomorphological area, but also roughly coincides with the *civitas Batavorum*, which was an administrative unit within the Roman Empire and the home of the ethnic group of the Batavians. The southern part of the *civitas Batavorum* is excluded. Because of its sandy soils, there are very few sites with animal bones from this region.[1] Just as important is that the difference in geomorphology may have resulted in different agrarian regimes. Therefore, the Pleistocene

[1] An exception is Oss-Ussen. Lauwerier/IJzereef 1994.

Fig. 1.1. Location of the research area.

sandy soils form the southern border of the research area. In the north, the river Rhine forms the frontier of the Roman Empire. To the east, the border of the Netherlands with Germany is used to define the research area. This is also the point where the river Waal splits off from the river Rhine, creating an area enclosed by rivers – with the Meuse coming from the south – rather than an area with a river running through it. To the west, a change in geology from river clays to peat and sea clays forms the final boundary of the research area. While the chronology of the individual sites was respected in this study, in order to make meaningful comparisons the commonly accepted chronology for the Roman Netherlands was used to study developments over time. This chronology consists of three periods: the Early Roman period: 12 B.C. – A.D. 70; the Middle Roman period: A.D. 70-270; and the Late Roman period: A.D. 270-350.

1.1.3 Aim, research questions and approach

The aim of this study is to examine the zooarchaeological data set from the Roman Dutch River Area for evidence that sheds light on the interaction between farmers and urban and military consumers, and for developments in animal husbandry that can be related to market production. Interaction would have taken place if the army camps and the town of Nijmegen were supplied with food and products that were produced by the farmers in the research area. In order to understand agrarian production and consumption, data from producer sites (rural settlements) and consumer sites (military camps, town and temples) need to be included, since they provide different parts of the puzzle. For the rural settlements, I will characterise the agrarian economy and trace developments in farming, especially in animal husbandry, that occurred during the Roman period. I will then try to answer the question whether developments can be related to production for the Roman market. An important question is who controlled the process of agrarian production. Did the demand from consumers drive production, or did producers decide what was sold? While I am also interested in variability in production strategies between and within rural communities, the focus in this study will be on general patterns that can be identified in the agrarian production of the rural settlements. A previous study focused on individual households in order to find out the role of the individual in agrarian production.[2] While such an approach can give new insights into the functioning of rural communities, the lack of suitable data sets meant that it could not be taken further in the current study. For the consumer sites, consumption patterns will be investigated, and also whether animals supplied other products. Data from rural and consumer sites will be compared in order to establish what products could be and were supplied from local sources, and to trace the origin and movement of agricultural products.

This study will take a regional approach to reconstruct farming and food supply for the *civitas Batavorum*. The research area is unique in the extent to which it is known archaeologically: not only is there a long academic tradition of archaeological research into the Roman period,[3] but in the last fifteen years rescue archaeology has increased the number of excavations enormously. The quality of the data set, particularly with regard to rural settlements, is high: it includes several sites that cover the entire Roman period and have been excavated completely. Lauwerier published his regional study on animal husbandry in 1988 (including 12 sites);[4] since then, the number of sites with zooarchaeological data has grown to 72 (this study). Although the number of consumer sites for which data are available is smaller than the number of rural sites, it includes some large assemblages. By concentrating on producers as well as consumers, we can investigate the effect of market production on local communities.

The study has two sides: first, it is a synthesis of animal husbandry and the consumption of animal products in the Roman Dutch River Area. To that end, it will bring together all zooarchaeological data from the last decades, and reconstruct farming and dietary patterns. Second, it addresses questions of wider relevance for farming, food supply and the Roman economy. What strategies were used in the provisioning of the Roman army and town in the research area? How did local farming communities respond to the increased demand for agrarian products? How did they achieve a move from subsistence farming to market production? What strategies did they employ to increase their production? Roman society and economy were strongly based on farming, and a good understanding of farming is therefore crucial if we want to understand the Roman Empire. Similar developments in animal husbandry occur throughout the Roman provinces, as will become clear from the parallels that will be mentioned. However, regional differences can be noticed.[5] Each region had its own history, culture and environment, which meant that each region had to find its own solution to deal with the Roman occupation and the challenges this provided for animal husbandry and food supply. This study will reveal what the solution was in the Dutch River Area.

To achieve the objectives, a number of smaller research questions will be addressed. Animal bones form the basis of this study, and the questions below can directly be linked to certain aspects that are commonly investigated in zooarchaeological studies: species proportions, age and sex, skeletal elements, butchery and measurements. While the main focus is on animal husbandry, as evidenced by animal remains, some information from archaeobotanical research is also included. After all, arable farming is inextricably linked with animal husbandry in a mixed farming system. This subdivision will be followed throughout this study.

1.1.3.1 Species proportions

The proportions in which the four main domestic mammals (cattle, sheep/goat, horse and pig) contribute to the animal bone assemblages form the basis for interpreting their importance in agrarian production and as food. Apart from the domestic mammals, wild mammals, fish and birds provided another source of food. Animal species that did not occur naturally in the research area provide evidence for trade. Chicken was introduced in the research area by the Romans, and its presence in rural settlements is an indication for connections between rural inhabitants and the Roman army or town. Species proportions will be examined to answer the following questions:

- What was the relative importance of the four main domestic mammals? Are there any developments over time in species proportions? Can any differences be observed between individual sites,

2 Groot 2011b; 2012b.

3 E.g. Aarts 2014; Heeren 2009; Lauwerier 1988; Nicolay 2007; Roymans 1996; 2004; Van Driel-Murray 2003; Vos 2009; Willems 1984; Willems/Van Enckevort 2009.

4 Lauwerier 1988.

5 E.g. Groot/Deschler-Erb 2015; 2016.

and between rural and consumer sites? What do these species proportions say about meat provisioning in consumer sites?
- To what extent did hunting and fishing contribute to the diet? Is there any evidence for trade in animal foods, such as seashells?
- How important was chicken in rural and consumer sites?

1.1.3.2 Age and sex

Together with species proportions, data on slaughter ages and the sex of livestock form the main information on animal husbandry. Mortality profiles of livestock can be used to reconstruct exploitation strategies, with meat, milk and traction (in the case of cattle) all leading to different profiles. In the case of consumer sites, mortality profiles provide indirect information on production, as only those animals selected for the market are represented. In that sense, they may give insight into what this selection was based on, and thus into who actually selected the animals (the farmer or the consumer). Data on age and sex will be used to answer these questions:
- What can we say about the exploitation of livestock? How important were secondary products? At what ages were animals slaughtered for meat?
- Are there any developments over time in the mortality profiles for the main species?
- How do slaughter ages for livestock from rural and consumer sites compare? What does this say about exploitation of animal herds and decisions about selection?

1.1.3.3 Skeletal elements

Investigating which skeletal elements are present or absent, or under- or overrepresented gives insight into butchery and processing of animals and into the production and consumption of certain animal products (such as hides and smoked meat). The questions related to skeletal element distribution that will be addressed in this study are:
- Can any patterns be identified in skeletal element distribution, such as developments over time or differences or similarities between sites, and if so, how can they be explained?
- Is there any evidence for the production of cattle hides in rural sites? If so, at what scale did this take place?
- Are there indications that certain meat products, such as smoked shoulders or brawn, were produced in rural sites?
- Do consumer sites show evidence for processed meat and industrial processing of animals?

1.1.3.4 Butchery

Butchery marks on animal bones provide information on whether meat of livestock was consumed, and on how an animal was processed from carcass to meat. Butchery practices vary between cultures, and are also dependent on the tools that are available. Changes in butchery practices can thus tell us about cultural changes. Butchery marks also provide insight into the scale and efficiency of butchery. Large-scale processing of livestock for meat involves professional butchers and standardisation of butchery practices. Butchery marks are included in this study to answer the following questions:
- Did butchery practices in rural sites change during the Roman period, and if they did, in what way?
- Is there evidence for the use of new tools in rural sites?
- Do butchery marks provide evidence for the consumption of horse meat?
- What is the evidence for large-scale butchery and processing of cattle in urban and military sites?

1.1.3.5 Biometrics

Measurements of animal bones can reveal changes in size and shape of livestock. These can reflect changes in exploitation or nutrition or genetic changes. Genetic changes are caused by the import of new stock or by interbreeding with animals outside the local population. Comparing measurements from different rural sites can say something about the interaction between different rural communities, in the form of exchange of breeding stock. Comparing measurements of livestock from rural settlements with those of livestock in consumer sites and between military and urban sites can tell us whether animals were supplied from local sources or imported, and whether army and town were supplied from the same sources. Measurements can also be used to reconstruct withers height. The focus in this study will be on cattle, but data on withers height from the other main domestic animals will also be included, in order to answer the following questions:

- What do bone measurements say about the development in the size and shape of cattle over time? Can size increases be dated? Was size increase a uniform process, or did it occur at different times in different sites? Was it a gradual or a sudden transformation?
- What was the variety within the rural cattle population in the Dutch River Area? What does this say about the interaction between rural sites?
- Is there a difference in size and shape between cattle from rural settlements and cattle from consumer sites? What does this say about the interaction between rural and consumer sites?
- Is there a difference in size and shape between cattle from military and urban sites? What does this say about the supply to army and town?
- Are there any developments in withers height of cattle, horse and sheep? Are there any differences in withers height of these animals between rural and consumer sites?
- Is there any evidence for the import of livestock from outside the Dutch River Area?

1.1.3.6 Archaeobotany

In the Roman Dutch River Area, mixed farming was practised. In this system, the growing of crops and the keeping of animals is complementary and interdependent. Animals provide manure, pull ploughs and are used for threshing, while arable farming provides fodder for livestock. Although this study focuses on animal husbandry, archaeobotanical data were included in the study to some extent, to achieve a more complete picture of agrarian production and consumption. Furthermore, these data also provide information on consumption patterns and trade. Archaeobotanical data will be examined to answer the following questions:

- What species of cultivated and wild food plants are present in rural and consumer sites?
- Is there any indication for imports from outside the research area?

1.2 THE DUTCH RIVER AREA IN THE ROMAN PERIOD

This paragraph focuses on aspects and developments in the region that are relevant to agrarian production and trade. These include the possibilities and limitations of the landscape, the presence of the army, infrastructure, the construction of the *limes*, the development of the town of Nijmegen and the administrative and political framework.

1.2.1 THE DYNAMIC LANDSCAPE OF THE RIVER AREA

Since agriculture is dictated to a large extent by the local landscape, it is important to understand the landscape of the Dutch River Area. This Holocene landscape was defined by river channels and their sedimentations. The meandering rivers changed their course over time and often flooded their banks in winter. The river banks or natural levees were higher than the surrounding land and composed of sandy-silty clay, whereas the flood basins were low-lying, with soil consisting of clay

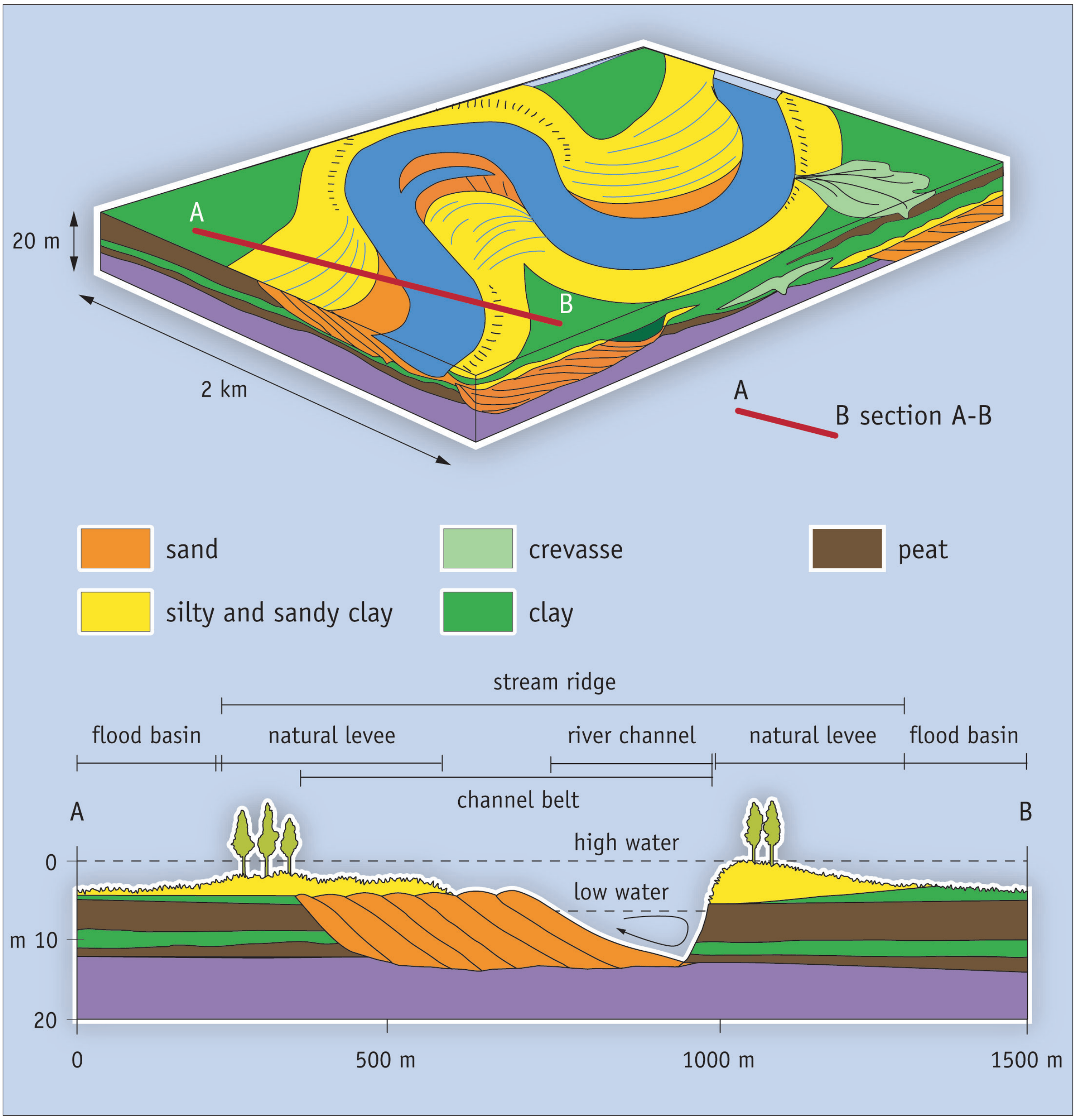

Fig. 1.2. A cross-section through an active river, with the river channel, streamridge and flood basin (after Berendsen and Stouthamer 2001, fig. 3.4).

sediment.[6] When a river was no longer active the river bed silted up. A stream ridge consisted of the old river bed with its sandy deposits, possibly with a residual channel, and the former river banks. A stream ridge remained a higher feature in the landscape. Active river channels, stream ridges and flood basins formed the main elements of the landscape of the Dutch River Area (fig. 1.2).

Banks of active rivers were originally covered by forest consisting of willow, alder, ash, oak and elm. Fossil river banks, so-called stream ridges, were covered by oak, ash, elm, and a variety of bushes and herbs. The flood basins were mainly covered by marshy vegetation such as reed and sedge, with alder and willow growing in the higher parts, which were dry in the summer. Riverine forest was cleared

[6] Berendsen/Stouthamer 2001, 23-24.

from the Bronze Age onwards to make land available for settlements and arable agriculture. Cutting of trees and grazing of marsh vegetation in the flood basins allowed grassland to be established.[7]

The stream ridges were most suitable for habitation and arable agriculture. The amount of produce that could be grown was limited by the surface area of the stream ridges. We should, however, be careful not to define a landscape in a negative way, focusing on the restrictions.[8] The variations in the landscape of the Dutch River Area offered plenty of opportunities, especially for a people adapted and used to the dynamic character of the landscape. The flood basins offered plentiful grazing in summer. Livestock would thrive on the rich grassland. Although the surface area was limited, the drier and sandier stream ridges offered fertile ground for arable agriculture. The use of crops adapted to the local environment ensured successful harvests. Rivers could be used as channels for quick and easy communication and transportation of goods. Rivers and natural ponds were inhabited by various species of fish. The flood basins and what remained of the riverine forest offered a good habitat for wild mammals, although as we shall see this source of food was only used in a limited way.

1.2.2 Romans and Batavians

The Batavians first arrived in the eastern part of the Dutch River Area in the second half of the 1st century B.C., after the local tribe, the Eburones, had been decimated by Caesar. Motives behind this move could have varied from demographic pressure to promises made by the Roman authorities. For the Roman authorities, the settling of friendly tribes on the southern bank of the Rhine would give them tighter control of the frontier zone. The Batavian immigrants almost certainly fused with the remaining Eburones to create a new ethnic group.[9]

A vital factor in the development of this region was the system of ethnic recruitment by the Roman army. Exempt from taxation, the Batavian tribe that inhabited the Dutch River Area was obliged to supply soldiers for auxiliary units as well as the Imperial Guard.[10] Around 5,000 men served in the Roman army at any time. The extent of recruitment was such that every community, and perhaps even every family, had a member who was serving in the army.[11] The substantial drain of men to the army would have had a big effect on the small rural communities.[12] Based on the belief that the region was poor and offered very limited potential for agriculture, Van Driel-Murray proposes a system of intensive horticulture, in which women produced vegetables, cheese and eggs on a small scale for nearby markets. Cattle were primarily kept for manure.[13] In such a system, the men serving in the army would not be missed, and even brought in army pay, which would have been spent on clothing and food.[14]

After a period of 25 years, soldiers were released from the army, and were free to return to their families and homes. While not every soldier returned to the *civitas Batavorum* – some may have married and preferred to settle down elsewhere, while others failed to survive army service – enough did so to have a large effect on Batavian communities.[15]

While temples and towns were built in a Roman style and people started to adopt Latin names, most Batavians continued living in traditional farmhouses.[16] New identities were constructed in which both the old warrior and pastoral values and the new values connected with Roman civilisation were represented. The Batavian elite served as officers in the Roman army and were mediators between

7 Lange 1990, 18-19.

8 Van Driel-Murray 2003, 205.

9 Roymans 2004, 19, 25-27, 55.

10 Tacitus, *Germania* 29; *Historiae* 4.12, 5.25; Roymans 2004, 55-58.

11 Willems 1984, 235.

12 Van Driel-Murray 2003, 207.

13 Van Driel-Murray 2003, 205-206.

14 Van Driel-Murray 2003, 208.

15 Derks/Roymans 2002, 100-102; Heeren 2009, 157-160; Nicolay 2007; Vos 2009, 243-247.

16 Roymans 2004, 252-253.

their fellow Batavians and Roman military culture. The Batavians who served in the army may have facilitated trade contacts between the Roman army and the rural settlements in the Dutch River Area. Recent research has identified a relation between developments in animal husbandry and veterans, suggesting that their influence was not just cultural, but also economic.[17]

1.2.3 Early Roman period: 12 B.C. – A.D. 70

The Roman army first reached this region around the middle of the 1st century B.C.[18] A more permanent military presence did not exist until the reign of Augustus. In 19 B.C., a legionary camp was built on the Hunerberg in Nijmegen because of its strategic location on a high ice-pushed ridge. Nijmegen was one of the operating bases for the planned conquest of *Germania*.[19] The camp was abandoned between 15 and 12 B.C. It was succeeded by another large fort on the Kops Plateau in Nijmegen, which was built around 12 B.C.[20] Early in the 1st century A.D., a few strategically located forts were built: Meinerswijk, Vechten and Velsen.[21] Attempts to conquer *Germania* were abandoned by Tiberius in A.D. 16-17, after which the Rhine marked the edge of the Roman Empire. In the 40s, a series of auxiliary forts was built on the southern bank of the river Rhine, expanding the existing military infrastructure and forming a permanent line of defense. In the research area, new *castella* were built in Vleuten-De Meern and Utrecht. The function of the *castella* built at this time seems to have been directly related to the river, either in preparation for the conquest of Britain or to control pirates.[22] After the Batavian revolt, *castella* were added in Kesteren and Maurik.[23]

The civilian settlement *Oppidum Batavorum* was situated in modern Nijmegen, on and around the Valkhof, on the southern bank of the river Waal. This was the capital of the Batavians, founded c. 10 B.C., at the same time as the fort on the Kops Plateau. The urban centre *Oppidum Batavorum* was designed and built by the Romans, with the purpose of controlling the new *civitas*. Evidence has been found for a planned lay-out. Most of the buildings were built in wood, although some stone foundations have been found. During the Batavian revolt, a fire destroyed most of the budding town, and development was halted. Few Batavians lived in the town; inhabitants were mostly craftsmen, officials, retired soldiers and immigrants.[24] The absence of public buildings or a town wall means that this cannot be called a proper town, but for this study it should be regarded as such, as it was very different in character from the rural settlements in the region, and inhabited by non-agrarian people.

The exact year in which the administrative district of the *civitas Batavorum* was founded is uncertain. This moment was long believed to have taken place in the late 1st century A.D., but recently Panhuysen has interpreted a victory pillar dating to A.D. 17-19 as marking the foundation of the new *civitas*.[25] More evidence for the early formation of the *civitas* is found on the altar stone from Ruimel, which mentions a *summus magistratus* of the *civitas Batavorum*, and dates to the first half of the 1st century A.D.[26]

In A.D. 43, eight Batavian cohorts were sent to *Britannia*. The movement of 4000 men out of their home region must have had social consequences.[27] In the late 60s, heavy recruitment took place among the Batavian population. Until they abandoned Nero, the imperial body guard also consisted of Batavian soldiers. A.D. 69 was the year of the Batavian revolt. The increasing pressure on the Bata-

17 Groot 2011b; 2012b.

18 For a comprehensive account of the early military occupation of the region, see Polak/Kooistra 2015.

19 Bechert/Willems 1995, 24-25.

20 Haalebos *et al.* 1995.

21 Bechert/Willems 1995, 24.

22 Polak 2009.

23 Bechert/Willems 1995, 15, 25.

24 Willems/Van Enckevort 2009, 70-72.

25 Panhuysen 2001 in Willems/Van Enckevort 2009, 71; Willems/Van Enckevort 2009, 22, 71.

26 Willems/Van Enckevort 2009, 22, 72.

27 Willems/Van Enckevort 2009, 23.

vians, a confusing political situation and the person of Julius Civilis all led to the revolt, which was not intended to win independence, but rather to re-establish the old alliance. At the end of 69, the new emperor Vespasian sent a large army north to suppress the revolt. In the autumn of 70, *Legio II Adiutrix* came to Nijmegen, but left for *Britannia* soon after. The revolt was ended by a treaty between Julius Civilis and Q. Petillius Cerialis, renewing the old alliance. [28]

1.2.4 Middle Roman period: A.D. 70-270

The years between A.D. 70 and 270 were a period of economic prosperity and development. The frontier zone was incorporated into the Empire when it was converted into the province *Germania Inferior* somewhere between 82 and 90.[29] The second half of the 80s saw the construction of the *limes* road. This road was located on the southern bank of the river Rhine. Recent research has not only led to a later construction date, but also to a different function: a short and fast route through the *limes* zone rather than protection of the river frontier.[30] The existence of secondary ditches is interpreted as an indication that the zone adjacent to the *limes* road was used for transport of livestock.[31]

In the late 1st century, *Legio X Gemina* had replaced *Legio II Adiutrix* and built a legionary fortress on the Hunerberg. The support of Germanic tribes from across the Rhine to the Batavian revolters had highlighted the lack of loyalty and the military potential. The legion had to defend against attack, guard the loyalty of local tribes, and improve the infrastructure in the province by constructing roads and building forts.[32] The *castra* on the Hunerberg was surrounded by *canabae* on three sides. A large *forum* has been excavated in the eastern *canabae*. The square inside was almost entirely filled with postholes, many of which were organised in a linear way. The postholes have been interpreted as the remains of a livestock market, with the postholes representing the remains of enclosed areas or posts to which animals were tied.[33] Constructions of tiles found within and just outside the *forum* have been suggested to be snack bars,[34] which would certainly fit with the congregation of a large number of people at a livestock market.

After the destruction of *Oppidum Batavorum* by fire during the Batavian revolt, a new urban centre was founded to the west. With a bathhouse, temples and a *forum*, this can be considered a proper Roman town. Not long after A.D. 100, market rights were granted to the town by Trajan, and the town received its name: *Ulpia Noviomagus*. It is possible that this was done to give the town an economic boost to make up for losing the legion; on the other hand, it may also be part of a general strategy to further integrate the *civitas*. In the later 2nd or early 3rd century, the town received town privileges, when it was formally named *Municipium Batavorum*.[35] Urban habitation is characterised by long plots perpendicular to the road and wooden buildings. The pottery produced in Nijmegen was partly for domestic use (sold on local markets), but the majority was used as containers for food produced in Nijmegen. This production may have been connected to the supply of the legionary fortress, but could also be a sign of an economic relationship with the surrounding countryside. In the last quarter of the 1st century, imported pottery is mostly lacking (apart from tableware and *amphorae*). After the town had received market rights, the effects are visible by large quantities of imported pottery. Catastrophic events at the end of the 2nd century are reflected in burned layers, but the cause is not certain. Parts

28 Tacitus, *Historiae* 5.26; Roymans 204, 209, note 466.

29 Willems/Van Enckevort 2009, 25, 75.

30 Luksen-IJtsma 2010.

31 Luksen-IJtsma 2010, 65, 67.

32 Willems/Van Enckevort 2009, 24.

33 Driessen 2007, 130-135.

34 Willems 1990, 55-56. An interpretation as ovens for smoking meat seems less likely, considering their location and the lack of similarity with smoking ovens found elsewhere. Similar structures have been found in Bad Wimpfen, where they were interpreted as grills; evidence was also found for grilled cattle muzzles. Filgis 1988; Kokabi/Frey 1988.

35 Willems/Van Enckevort 2009, 74-79.

of the town were rebuilt, but not the temples. The main indications at this time are for the activity of butchers and potters. Germanic raids put an end to the town in 260/270.

The countryside reached a peak in its population density in the Middle Roman period, with large numbers of settlements scattered around the region. Most of these settlements were small, consisting of one to five simple farms. A few sites show evidence for buildings in stone or the use of Roman building materials, and are interpreted as *villae*.[36] An important development is the digging of ditches, which form field systems dividing or marking the countryside. The role of these field systems is still debated, and variously interpreted as related to taxation, drainage, leading water to the settlement, or extension of arable land to increase production.[37]

1.2.5 Late Roman period: A.D. 270-350/450

Chaos ruled in the last decades of the 3rd century A.D., with frequent invasions from people living north of the river Rhine into the *civitas Batavorum*. The Germanic immigrants started to control the countryside. The presence of these people is traced through typical house plans and pottery.[38] There was an increasing contrast between the Roman urban and military centres and the countryside.

During the 4th century, some but not all of the forts along the Rhine were rebuilt.[39] Until the middle of the 4th century, the Lower Rhine Area remained intact in an organisational and defensive sense. Around A.D. 350, this all changed. There was a struggle over the Empire, and Germanic tribes used this opportunity to cross the river Rhine. This meant the end of the *civitas Batavorum*. The frontier was rebuilt by Valentinian shortly after, and some stability returned. Salian Franks had settled in the region in the early 5th century, probably in return for military support. The end of the Late Roman period is arbitrary: either the end of the *civitas Batavorum* or the year 454, when Cologne fell into Frankish hands. Despite the dramatic developments of this period, habitation in Nijmegen continued. A *castellum* was built on the Valkhof, surrounded by heavy fortifications. Some civilian habitation was present on the Waalkade and south of Trajanusplein (St. Canisiussingel).[40]

Soil exhaustion has been suggested as a possible explanation for the decline in population and the economy.[41] Van Driel-Murray suggested that there may have been a relation between the economic collapse and population decline in the region and changes in recruitment practices.[42] The agricultural base was vulnerable because of the large population size and the dependence on the army for employment. While she is talking about the later 2nd century, it would have taken some time before the effects would be visible archaeologically. Indeed, the decline in the number of rural settlements starts around the turn of the 2nd/3rd centuries.[43] Vos does not see any evidence for famine or large-scale movement of people away from the region, and believes that the decline in rural sites can be attributed to a combination of factors: Chaucian raids in the later 2nd century, the change in recruitment, a pest epidemic and a rise in the water level in the Kromme Rijn area.

36 Examples are Druten-Klepperhei and Ewijk-Keizershoeve. Blom *et al.* 2012; Hulst 1978; 1980.

37 Heeren 2009; Groot/Kooistra 2009; Vos 2009. A similar development is found in the western part of the Roman Netherlands. Van Londen 2006.

38 E.g. in Tiel-Passewaaijse Hogeweg and Geldermalsen-Hondsgemet. Heeren 2006, 90; 2009, 72-73; Van Renswoude 2009b, 472.

39 Bechert/Willems 1995, 27.

40 Willems/Van Enckevort 2009, 27-28.

41 Groenman-van Waateringe 1983.

42 Van Driel-Murray 2003, 213-215.

43 Vos 2009, 259-260.

1.3 ECONOMIC NETWORKS AND FOOD PROVISIONING

1.3.1 THE ECONOMIC NETWORK OF THE DUTCH RIVER AREA

Several agents can be identified in the economic network of the Dutch River Area: the inhabitants of the rural settlements, the Roman army, inhabitants of the town of Nijmegen, traders or middlemen and the Roman authorities. They would have met in markets in towns and rural centres, or traders or middlemen could have come directly to the rural settlements to buy produce. These agents can roughly be divided into consumers and producers.

Producer site here means a rural settlement where agriculture was the main means of existence, and most food was produced locally, as well as an agrarian surplus. Of course, producers also consumed part of the food they produced, which complicates matters. To ensure continuity of production, it was also necessary to maintain the herds of livestock and to reserve sowing seed for next year's crop.[44] This means that only a small part of the produced food may have been available as a surplus. Agrarian production sites in the Roman period are mostly consumption sites with regard to pottery, metal etc.

Consumer sites are sites where the majority of people were not involved in agriculture. However, some food may have been produced by consumers: vegetables could be grown in small plots in the town, and especially pigs and chickens can be raised in towns. Moreover, producers of food were consumers of other products, such as pottery and textiles, which were produced in town (table 1.1). Textiles are an indirect agricultural product, since in complex societies the processing of wool often takes place in a different place from its production. Hides may also have been processed into leather in towns, and boneworking is another activity that requires raw sources deriving from agriculture. So the division into consumers and producers is clearly a simplification and only relates to agrarian products, such as animals and crops. Nevertheless, this division has been used to structure this study, and, despite its shortcomings, is useful to study food supply and agrarian production.

consumers			**producers**	
produced:	**consumed locally produced products:**	**acquired from outside the region:**	**produced:**	**consumed:**
pottery	meat	pottery	meat animals	pottery
leather goods	wool	wine/olive oil/fish sauce	wool	leather goods
textiles	hides	imported livestock	hides	textiles
other non-food products[45]	horses	salt	horses	other non-food products
	eggs	seashells	eggs	wine/olive oil/fish sauce?[46]
	cereals		cereals	salt
	vegetables		vegetables	seashells
	other plant foods		other plant foods	

Table 1.1. Some of the products that were produced and consumed in typical consumer and producer sites in the research area, illustrating the complementary functions of town and countryside. Raw materials such as timber, stone and clay were of course also important but have not been included here.[47]

44 Stallibrass/Thomas 2008, 151.

45 Such as glass, tiles and metal objects. Raw materials were gathered or acquired from inside or outside the research area.

46 *Amphorae* sherds are found in rural sites, but it is uncertain whether these reached the rural sites complete with their contents.

47 Carrington 2008, 19.

Fig. 1.3. Reconstruction of the rural settlement Tiel-Passewaaijse Hogeweg (from Groot/Kooistra 2009; illustration Mikko Kriek).

Consumers in the research area include the Roman army, townspeople and people visiting temples. The Roman army required food and other necessities. The size of the army in *Germania Inferior* varied. It started to decrease after A.D. 16-17, from a maximum of 42,000 men to 20,000 men from the early 2nd century onwards.[48] There were very few towns or urban centres in the Roman Netherlands. The most important one, and the only one in the research area, was the capital of the *civitas Batavorum* in modern Nijmegen. The population of Nijmegen in the late 1st century A.D. has been estimated at 5,000 civilians and 5,000 soldiers.[49] Between 71 and 102/104, the Tenth Legion was quartered in Nijmegen, which explains the large number of soldiers. Civilians not only lived in the town but also in the camp settlement or *canabae* surrounding the legionary fortress. *Canabae* were inhabited by merchants, shopkeepers, craftsmen, veterans, farmers and the wives and children of soldiers. All these people had close links with the Roman army. The *canabae* ceased to exist after the Tenth Legion left Nijmegen. From the early 1st century A.D. onwards, Nijmegen must have been an important market place for the surrounding region. Temples would not just have been focal points for religious activities, but also housed markets.[50] Cattle, sheep and pigs were frequently sacrificed on the temple site. Part of the animal was offered to the gods, but most of the meat was consumed by priests and members of the community.[51] The use of sacrificial animals in the temples meant that livestock had to be supplied from the surrounding settlements.

48 Alföldy 1968, 137-143, 149-152, 160-162; Polak 2009.

49 Willems 1990, 71; Willems/Van Enckevort 2009, 74.

50 Van Es 1981, 194.

The producers are the farmers living in the countryside. The rural settlements in the Dutch River Area were usually small, with only one to a handful of farmhouses (fig. 1.3). The typical farmhouse found in these settlements was the byrehouse, housing man and livestock under one roof.[52] Farmhouses were constructed from wood and wattle-and-daub, with thatched roofs. Despite the sporadic incorporation of Roman-style building materials, the native type of farmhouse stayed recognisable.[53] Apart from houseplans, other features typically found in rural settlements are granaries, wells, pits and ditches. A characteristic aspect of the Dutch River Area is the lack of Roman-style *villae*. Although some rural settlements have been labelled 'proto-*villae*', they were very different from the *villae* in other regions such as the loess area in the south of the Netherlands. The Roman *villa* was an agrarian operation with a stone main building built in Roman style. Arable agriculture and the production of a surplus for the urban market were the basis of the Roman *villa*. The rarity of *villae* in the Dutch River Area has been seen as a reflection of the poverty of the local people or of environmental constraints, but it has also been related to cultural values.[54] Instead of spending surplus wealth on stone-built houses, money was spent on pottery, bronze brooches, textiles, food and livestock. It is also possible that the Roman-style *villa* – being strongly associated with grain production – was not an obvious choice for a community with limited possibilities for producing surplus cereals.[55] A lack of impact on material culture has also been related with certain characteristics of the Batavians that made them suitable as soldiers: an emphasis on cooperation, sharing and conflict avoidance did not naturally lead to the accumulation of wealth by a few.[56] Since rural communities produced most of their own food, any surplus may have formed only a small part of the total agricultural production. The size of the rural population in the Batavian *civitas* has been estimated between 20,000 and 40,000 for the Early Roman period, and over 50,000 for the Middle Roman period.[57]

1.3.2 FOOD SUPPLY AND PROVISIONING

One of the basic needs of the army and the town was to arrange adequate food supply. There are different ways of procuring food. First, crops and livestock can be requisitioned directly from farmers. From the perspective of the rural settlements, this is not good news, since they would not receive anything in return. If not done sustainably, it could lead to food shortages. Archaeologically, requisition is difficult to detect in the rural sites, since there would be no traces of foreign material culture that is associated with trade. Age profiles of livestock in military sites can provide some insight, with a wider range of ages indicative of the army rounding up herds, and more restricted ages indicative of focused surplus production.[58]

A second way of food provisioning is through taxation. While the treaty between the Romans and Batavians exempted the Batavians from regular taxation, this situation may have changed after the Batavian revolt in A.D. 69.[59] The Batavians were now probably taxed not only for recruitment,

51 Roymans/Derks 1994, 31; Seijnen 1994, 171.

52 The style and construction of the byrehouse are not static, but develop during the Roman period. There were also some houses without a byre section. Vos 2009; Heeren 2009.

53 Roymans 1996, 74-76.

54 Roymans 1996, 73.

55 In the loess area, which is the *villa* zone closest to the research area, the production of high-quality cereals (mainly spelt) formed the agrarian base of the *villae*. Bakels 2009, 167; Kooistra 1996, chapter 4; Kreuz 2005; Roymans 1996. However, there are also *villae* where meat production formed the agrarian base, such as in the *villa* of Neftenbach, Switzerland. Deschler-Erb/Schröder Fartash 1999, 260-261.

56 Van Driel-Murray 2003, 209.

57 Vossen 2003; Willems 1984, 234-237.

58 Cool 2006, 186; Thomas 2008, 32; Thomas/Stallibrass 2008, 9.

59 Aarts 2014; Heeren 2009, 248; Vos 2009, 257, note 281.

but they had to pay taxes like any other people living in the Roman Empire. An agricultural surplus needed to be produced; this could be sold at the market for money to pay taxes or the surplus itself could be used to meet tax demands in kind. In this respect, taxation stimulates agrarian production.

Next, agrarian produce could be exchanged directly for other products, without the involvement of money. It is also possible that products were exchanged for labour, for example that soldiers of the Roman army assisted in harvesting crops in exchange for part of the crop. In this case, we would find no archaeological evidence for the exchange. Food, livestock and other agrarian products could also have been bought directly or indirectly (through tradesmen or markets).[60] The need for food in the town and army camps created an opportunity for the local inhabitants to sell their produce. Some foods were traded over long distances – such as wine and olive oil – or first processed before being sold, such as cuts of meat, whether preserved or not. However, military supply in the northwestern provinces mostly relied on local production.[61] In the context of this study, exchange or trade amount to the same thing: agrarian produce leaves the rural site, and imported material culture comes back in return, whether money is involved in the transaction or not (fig. 1.4).

Finally, it is possible that consumers produced some of their own food. Food may have been grown on military land, some animals may have been raised by soldiers, and the military diet was supplemented by hunting.[62] Urban people may have grown vegetables, kept a few pigs and chickens, gone hunting and fishing or collected wild fruits. While this certainly happened, it is likely to have been small-scale, and only covered a small part of the required food. Strategies may have differed between the army and the town, and over time. They could also have existed next to each other at the same time.[63]

While requisition and taxation offer one-sided benefits and leave little or no trace in rural sites, trade and exchange offer mutual benefits and result in a flow of imported material culture into rural sites. It is important to know how food supply was organised, since this affects how we perceive the rural people. Were the rural people self-sufficient and independent producers or entrepreneurs? Or were they tax-burdened slaves of the Roman occupation? Wells proposed that the indigenous people in the northwestern provinces were active participants in trade and the supply of goods to the Roman army.[64] The reliance of the army on local production for many goods implies that negotiation and interaction were more important than power in relationships between the army and local people.[65] Plenty of imported material culture has been found in rural sites in the research area, and coins of all denominations are common, so we can be certain that market transactions existed. However, this does not prove that the other strategies did not also take place.

In her study of early city states in the Middle East, Zeder investigated the mode of distribution of meat.[66] While far removed in time and space from our research area, there are some similarities in economic system, mainly the complexity and degree of specialisation. Her main concern was the degree to which the state controlled production and distribution of meat. She differentiated between direct and indirect distribution, explicitly described her predictions for the effects of the different modes on animal species, slaughter ages, skeletal elements and butchery patterns,[67] and then tested these predictions in her case study. In direct distribution, the distance between consumer and producer is small, farmers are in control of supply and herd security is the priority: the result is a diversity in products, similarity in species proportions between town and countryside, a combination of young,

60 Military contracts, with or without fixed prices, are a special type of direct purchase. Davies 1971, 123; Thomas/Stallibrass 2008, 1.

61 Thomas/Stallibrass 2008, 9.

62 Davies 1971, 123-124, 126, 128, 141.

63 The overwhelming impression of the Roman economy and food provisioning is that of complexity. The Vindolanda tablets are a good example. Grønland Evers 2011.

64 Wells 1996.

65 Wells 1996, 8.

66 Zeder 1991.

67 Zeder 1991, 36-43.

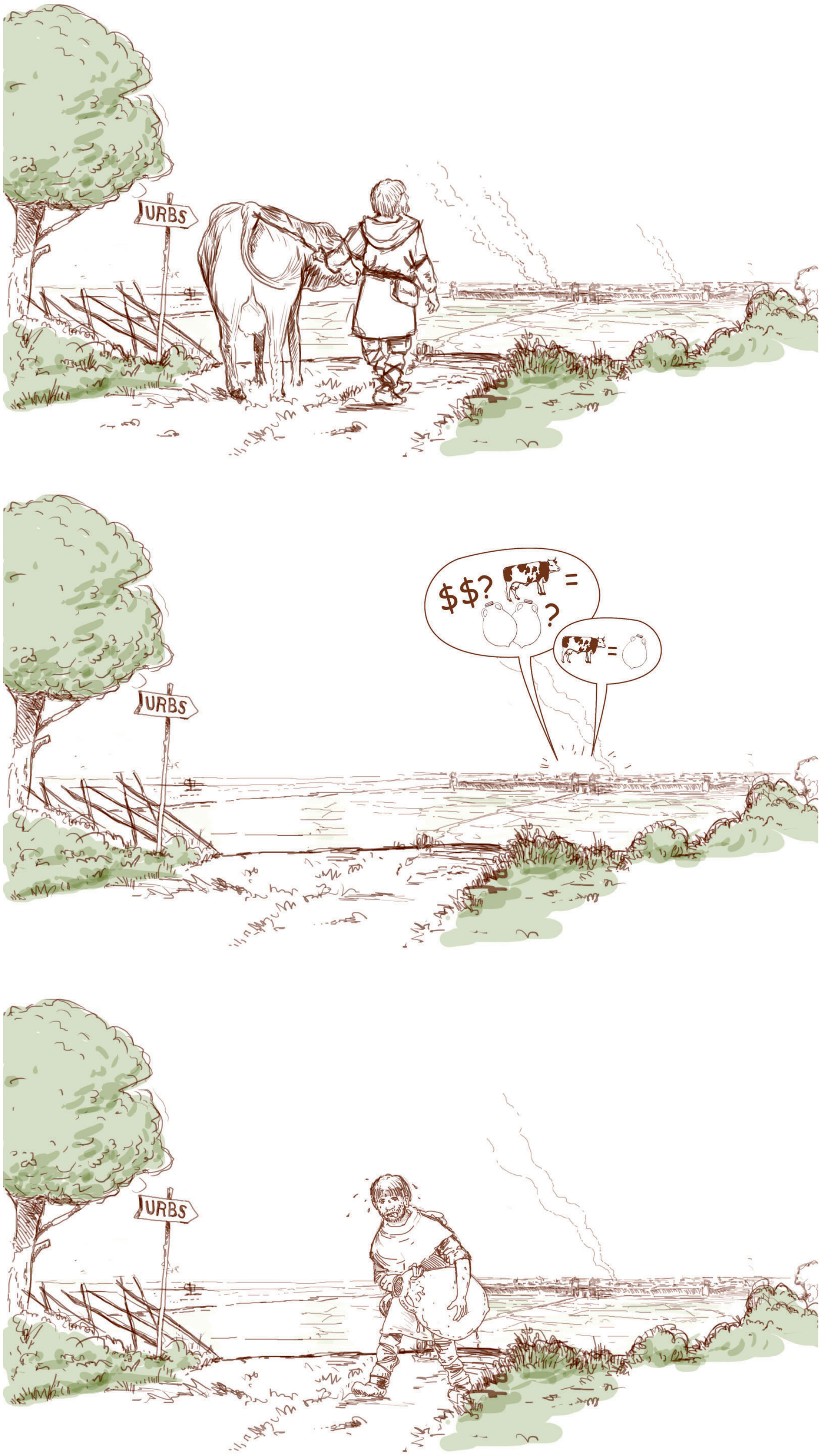

Fig. 1.4. The Roman market as a black box: we know that agrarian products went to the market, and we know that imported material came back in return, but we are not sure whether there was always money involved in these transactions.

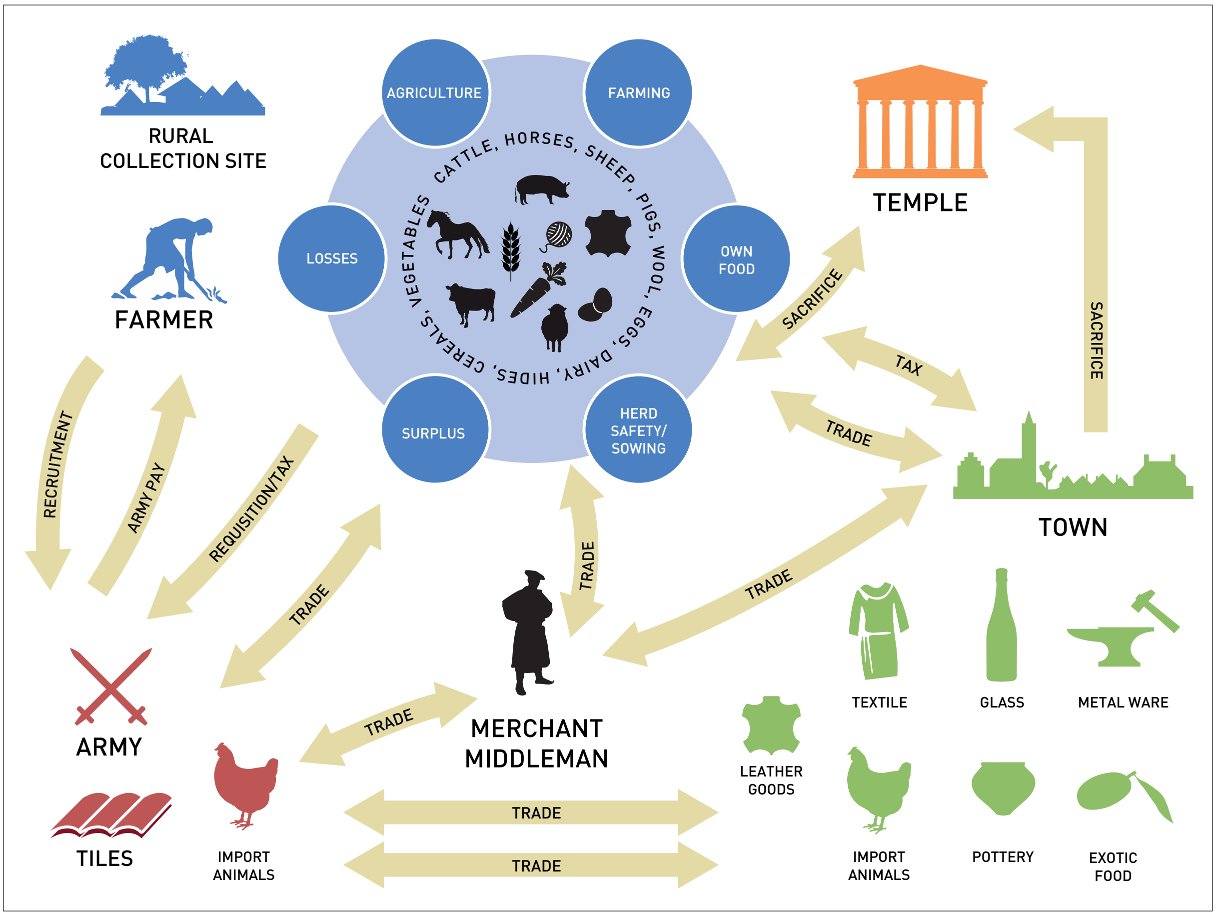

Fig. 1.5 Simplified model of the economic network in the *civitas Batavorum*.

surplus males and older animals, presence of all body parts and diversity in butchery practices. In indirect distribution, the distributor is in control and aims for maximum efficiency: the expectation is less diversity, animals with the most meat per animal, different species proportions in town and countryside, an emphasis on young adult animals, selection of body parts and standardisation in butchery practices. This model can also be used to investigate how meat was supplied to town and army in the Roman period,[68] specifically whether the farmers controlled supply or whether this was regulated by the Roman authorities. Indeed, it has already been used in an earlier study of the region.[69]

Unless goods were exchanged directly for other goods, knowledge of the use of money was necessary for a market system to develop.[70] The first half of the 1st century A.D. was a period during which both this knowledge and money itself spread rapidly through the Dutch River Area. Batavian soldiers and ex-soldiers played a crucial role in this process. At this time, Batavian troops were stationed in *Germania Inferior*. During visits to their home villages, part of their army wages would be left behind. Roman coins dating to this period are frequently found in rural settlements. More crucial is that the soldiers would pass on their knowledge about how money could be used. The low amounts of import-

68 A link between religion (sacrifice) and meat has been claimed for the Roman period, but the evidence for abattoirs and meat markets in Roman towns suggests that not all meat derived from sacrificial animals. Belayche 2008; De Ruyt 2008; Scheid 2008; Van Andringa 2008.

69 Filean 2006. Filean considers age and sex the most promising indicators for direct or indirect distribution. Filean 2006, 132.

70 This paragraph is based on Aarts 2014.

ed pottery in the first decades of the Roman period suggest limited trade between the rural settlements and the army. At this time, the civilian settlement in Nijmegen may not yet have had a significant market function. A substantial increase in imported pottery in rural settlements in the Dutch River Area in the Flavian period implies the existence of trade, and with it, an increasingly monetised society.

Fig. 1.5 is a simple model of the main agents in the economic network of the Roman River Area, the nature of the interactions between them and some of the products that may have been involved. Each farmer may only have produced a small surplus, but considering the population density, this could have amounted to a large total agrarian surplus.

1.4 FARMING IN A MARKET ECONOMY

1.4.1 FACTORS INFLUENCING FARMING STRATEGIES

There are many different factors that influence farmers' decisions. Some may have been relatively constant, while others changed during the Roman period. First, the potential of the landscape and climate for farming (soil, temperature, rainfall, danger of flooding) determined to a large extent what crops could be grown and what animals could be raised, and also where. In the river landscape, crops were grown on the higher areas, while livestock was grazed in lower-lying areas, which flooded when the rivers burst their banks. The lack of forest is often cited as an explanation for the low importance of pigs,[71] while in a similar way the regeneration of forest in the Late Roman period can be seen to explain the increase of pigs at this time. However, a warning against environmental determinism is found in the high proportions of sheep in the Iron Age and Early Roman River Area. Low proportions of sheep in wet areas have been explained by the susceptibility of sheep to foot rot, but clearly this did not prevent sheep from being kept in the River Area.[72] Second, the amount of land that was available, and the ratio between the land suitable for arable farming and as pasture (stream ridge or flood basin) determined how many crops could be grown and how many animals could be kept. This also depended on a third factor, the amount of labour that was available. Labour supply has a larger effect on arable farming, since this is more labour-intensive than animal husbandry. Next, demand also influenced what was produced. Without external demand for food or other products, farmers only had to consider the needs of themselves and their families. Reasons to produce more than required would be to avoid risks of bad harvests or epidemics,[73] or to produce food for communal feasts.[74]

The proximity to a market forms another factor, together with the infrastructure. If it is not possible to transport food to market before it spoils, then there is no point in producing it. For most livestock, which would have been walked to market alive, or cereals, which keep well, markets in the immediate proximity of the farm would not have been necessary. There is also a cost factor involved here: the cost of transport must be less than the proceeds. Connections and networks may also have been important, especially when selling products directly to the army. Veterans would have an advantage here, as they had connections and knew what the army required. Next, technology and know-how played a role in agrarian production. This includes the farming tools that were available, ways of storing crops, ways of draining land and improving soils, and knowledge on providing the best care and fodder for livestock.

71 E.g. Cavallo *et al*. 2008, 74 ; Kooistra 1996, 124; Lauwerier 1988, 127-128; Prummel 1979.

72 E.g. Lauwerier 1988, 128; Peters 1998, 237; Prummel 1979; Thomas 2008, 36; but see Kooistra 1996, 124 for a contrary opinion. In some cases, wet areas have been assumed to be unsuitable for sheep rearing, despite evidence to the contrary. Van Driel-Murray 2003, 208.

73 Halstead/O`Shea 1989.

74 Dietler 1996; Hayden 1996.

Indeed, the increase in cattle size during the Roman period has been attributed (in part) to improved animal husbandry techniques.[75] Finally, it is likely that farming decisions were not just influenced by economic concerns, but also by social and ideological factors.[76]

1.4.2 Responses to increased demand

When farmers are faced with an increased demand for food, they can respond in different ways to accommodate this demand and increase their production.[77] Their first option is agricultural intensification, in which the yield per unit is increased. For arable crops, this can be achieved by manuring fields and weeding and watering crops, while for livestock, better nutrition and selective breeding of larger animals will achieve higher yields of meat. The second option is agricultural expansion, in which the number of units is increased. For arable crops, this means putting larger areas of land under cultivation, while for animal husbandry it means having larger herds. The last option is specialisation, which often leads to a higher degree of efficiency in production. Which option is chosen depends on the limits of the local landscape, the available labour and the available technology and knowledge.

For the Roman period, all three responses have been observed. Intensification of arable farming is deduced from higher slaughter ages of cattle – providing traction and manure – and intensification of animal husbandry can be seen in the increase in size of livestock.[78] There is some evidence for fodder, but the information is so scarce that it cannot be established whether this reflects an improvement in nutrition.[79] Expansion of arable farming is seen in Roman Britain, where pollen evidence for woodland clearance suggests an increase in arable land.[80] In the Netherlands, field systems laid out in the late 1st century A.D. could reflect an expansion of arable land, although this is just one of several explanations.[81] Evidence for expansion of animal husbandry is found for instance in Feddersen Wierde, where the number of cattle stalls increased from 98 to 443,[82] and in Wijk bij Duurstede-De Horden, where an increase in grassland was observed.[83] The larger granaries found in the Dutch River Area indicate an increase in the production of cereals,[84] but provide no information on how this was accomplished. Examples of specialisation in animal husbandry, although relative, are found in the research area, where wool production and horse breeding have been identified.[85]

1.4.3 The methodology of market production

Studying agricultural production for the market is not without its problems. First of all, the rural sites included in this study are producing food for their own subsistence in the first place. Surplus production for a market came second, and was carried out next to subsistence production. This means that the evidence for farming that we find is a mix of subsistence and surplus production. Food or animals produced as a surplus may only have been a fraction of what was produced for subsistence. A consequence of this is that it is unlikely that we will find clear signatures that indicate surplus production.

75 E.g. Lauwerier 1988, 168; Teichert 1984, 99.

76 Roymans 1999.

77 Groot/Lentjes 2013, 12-13. See also De Hingh 2000.

78 Groot 2008a, 74, 91-93; 2009a, 368, 384-385; Lauwerier 1988, 166-167. Larger cattle could also have been desirable for traction, in which case they would reflect intensification of arable farming.

79 Lange 1990, 118-122; Kooistra 2009a, 442, 447.

80 Dark 1999, 264.

81 Groot/Kooistra 2009, 3.2.2.

82 Wells 1996, 10.

83 Lange 1990, 146.

84 Groot *et al.* 2009.

85 Groot 2008a, 70-73, 77-91; 2008b; Laarman 1996b, 377.

Second, while one of the signs of market production is specialisation in certain animals or products, we would expect specialisation to be limited in extent. The reasons for this are that specialisation occurred next to subsistence production, and that it makes more sense from a risk management point of view to spread surplus production over different products. In that case, if disease strikes a herd, or a crop fails, all is not lost. Third, most livestock would have been transported alive, which means that they leave no trace in the rural site. While there are ways in which the origin of animals can be studied, such as stable isotopes, prevalence of non-metric traits, hornlessness in sheep and cattle, difference in dental wear and differences or similarities in size and shape,[86] these remain largely unexplored for the research area. Next, it is very difficult to quantify the amount of surplus that was produced. Quantitative models can give an indication of the possibilities for and limits of surplus production, but cannot prove what was actually produced.[87] Finally, if we want to compare data from rural settlements with their markets, then we need to know where the agricultural surplus was going. Large towns may be supplied from a large area, with different farms or settlements supplying different products.

1.4.4 Evidence for surplus production in the Dutch River Area

Several studies have investigated surplus production in the Roman Netherlands. Kooistra looked at the Kromme Rijn Area in the central River Area.[88] Types of evidence Kooistra used as indicators for surplus production are storage capacity (exceeding local requirement), the predominance of one species (indicating local specialisation), the underrepresentation of young animals, and the presence of imported items (bought with money earned by selling farm produce). Two granaries in Houten-Tiellandt with storage capacity exceeding local requirements, and the underrepresentation of cattle horncores in combination with a high average age, are interpreted as indicating surplus production of some cereals and cattle. The high proportion of horses suggests horse breeding for the military market.[89] A quantitative model was developed to estimate the possible extent of surplus production. This led to the conclusion that in the Early Roman period – when the population was small –, any ratio of meat to cereals in the diet is possible, as well as surplus production. With a large population size (Middle Roman period), the proportion of cereals has to be at least 65 %, and there is little room for surplus production. Kooistra concluded that although a substantial surplus may have been produced in the Kromme Rijn Area in the Early Roman period, the area was never able to feed the entire non-agrarian population. Local food supply for the non-agrarian population may have been marginal, especially in the Middle Roman period. Instead, surplus production focused on horses.[90]

A later study looked at different kinds of archaeological evidence from two rural settlements (of which Wijk bij Duurstede-De Horden is located within Kooistra's Kromme Rijn Area), and concluded that an agrarian surplus could have been produced, but that the nature and extent varied over time.[91] This confirmed the conclusion reached for Tiel-Passewaaijse Hogeweg that changes in species proportions and animal exploitation were a sign of relative specialisation, which was an adaptation to market demand.[92]

86 E.g. Bendrey *et al.* 2009; Berger *et al.* 2010; Maltby 1994; O'Connor 2000a; Thomas 2008; Viner *et al.* 2010.

87 E.g. Van Dinter *et al.* 2014; Groot *et al.* 2009; Kooistra 1996; Kooistra *et al.* 2013.

88 Kooistra 1996.

89 Kooistra 1996, 66-67; Laarman 1996a, 354, 356; Laarman 1996b, 377.

90 Kooistra 1996, 71-73.

91 Groot *et al.* 2009.

92 Groot 2008a; 2008b.

A recent study focused on the peat and coastal part of the *limes*, to the west of the research area.[93] Quantifying the needs of the army for wood, cereals and meat and comparing this to the possibilities for local production led to the conclusion that a combination of local and extra-regional provisioning was practised.

An important point to keep in mind when discussing surplus production is that this is likely to have been small-scale, and always came second to providing for the rural community's subsistence needs.

93 Van Dinter *et al.* 2014; Kooistra *et al.* 2013.

2. Archaeological sites: background

2.1 DATA AND METHODS

In the decades since Lauwerier's publication on animal husbandry in the Roman River Area,[94] many new archaeological excavations have been carried out, mostly developer-funded. The size of these excavations varies from small test trenches to large-scale excavations of complete settlements. The quality of the excavations and the archaeological reports also varies. Information for some sites is limited to animal bone data, with little information on the other archaeological finds and structures. Likewise, the size of animal bone assemblages and the detail in which they have been analysed and published is variable. Fortunately, several zooarchaeological colleagues were generous in sharing unpublished reports and primary data.[95]

The selection of sites for this study is based on the presence of animal bones, for which reports or data were available. The description of the archaeological sites in paragraph 2.3 includes some information on the most important archaeological finds and structures, the chronology, any remarkable finds that could be related to production or trade, any relevant botanical data and basic information on the animal bone assemblage. Z.1 lists all the sites included in this study. Site numbers refer to a map of the research area (fig. 2.1), while the codes are used in illustrations in chapters 5 to 7. The table further includes the type of site, the size of the animal bone assemblage (both total size and identified fragments only) and the date of the assemblage. The collection of animal bone data from these sites for this study focused on fragment counts for domestic and wild species, and for the main domestic species skeletal elements, age data, measurements and butchery marks. Not all data could be collected for all assemblages, especially for the smaller ones.

The numbering of the sites is not always logical. The numbers referring to site locations in some cases cover several separate sites. One number has been used where sites are close together, have been excavated by the same archaeologists and are published together. Examples are Huissen-Loostraat Zuid, sites A and D and Zaltbommel-De Wildeman, sites A, B and C. In some cases, animal bone assemblages from what is essentially the same site have been given a separate number, because they were analysed and published by different people. Examples are Huissen-Loostraat Zuid site D and Huissen-Loovelden Het Riet and four assemblages from the *canabae legionis* in Nijmegen. An assemblage from Wijk bij Duurstede-De Geer received two separate numbers because the two Roman phases have a very different character: in the Middle Roman period, the site was almost certainly military, while the Late Roman phase is a rural settlement. In the same way, the assemblage from Utrecht-LR46 has been split into two, since it included an assemblage from a rural settlement as well as an assemblage from a *vicus*.

The 72 assemblages have yielded a total of 192,504 animal bone fragments. This figure mostly excludes bird and fish bones. A total of 87,321 fragments was identified to species (45 %). Where information was available on the preservation of the animal bones, preservation was generally good.

94 Lauwerier 1988.

95 I am especially grateful to Kinie Esser and Joyce van Dijk (Archeoplan Eco) and Frits Laarman (Cultural Heritage Agency). Bill Whittaker was kind enough to send his original Excel file containing the primary data for several sites.

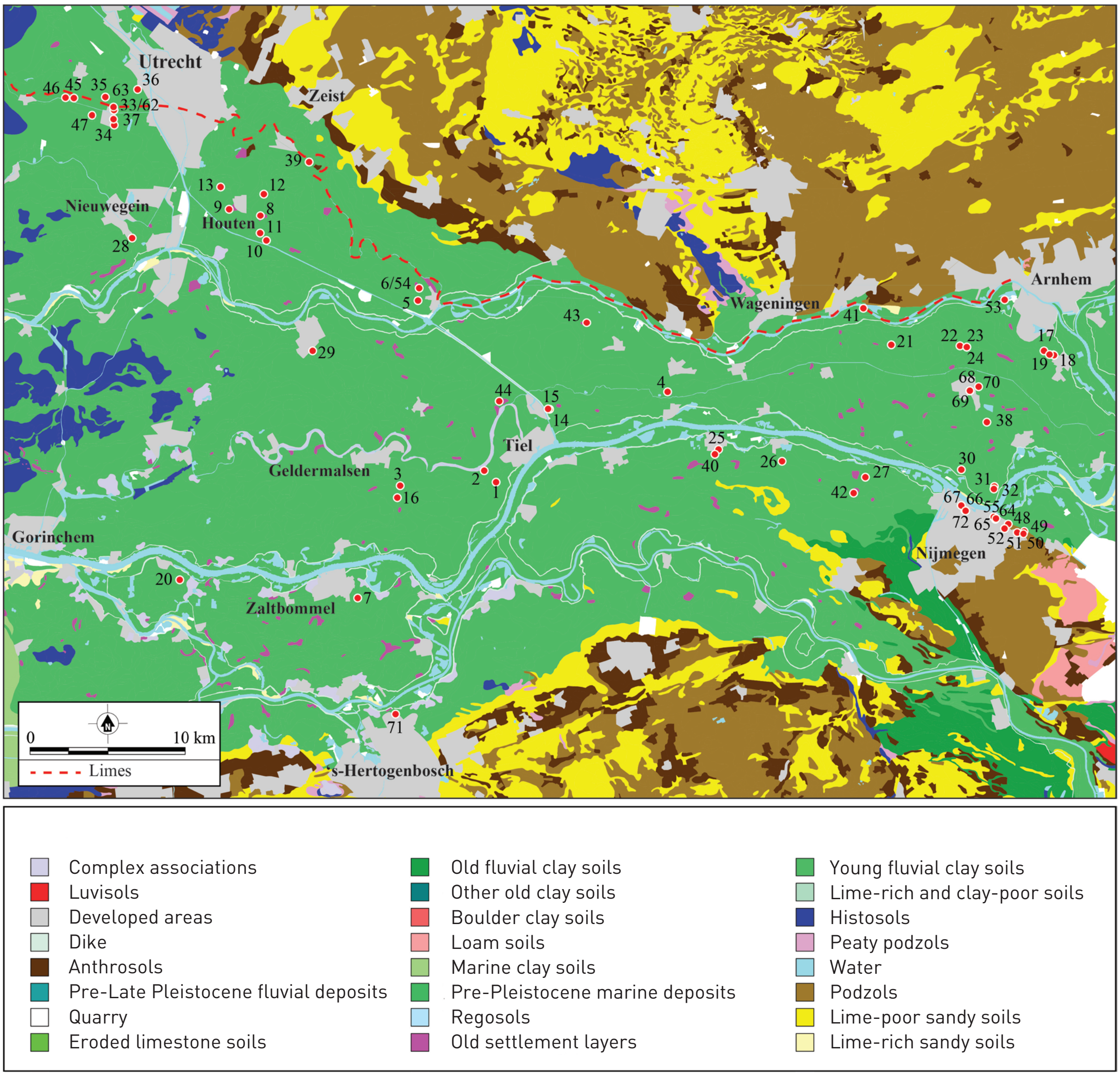

Fig. 2.1. Soil map of the research area with sites included in this study (Illustration by Jaap Fokkema).

45 assemblages are from sites classified as rural, and 27 from sites classified as military, urban or temple sites (table 2.2). The total number of fragments for the rural sites is 119,162, with 49,224 fragments identified (41 %). The total number of fragments for the military, urban and temple sites is 73,342, with 38,097 identified to species (52 %). The bias of the data is towards the rural sites, with 62.5 % of the total number of sites belonging to this category, 62 % of the total number of animal bones, and 56 % of the total number of identified animal bones. 26 assemblages (14 from rural and 12 from consumer sites) contain more than 1000 identified animal bones (table E2.1).[96] 32 assemblages (22 from rural and 10 from consumer sites) are small, with less than 500 identified fragments.

[96] Tables and figures not included in the text are preceded by an 'E' and can be found here: http://dx.doi.org/10.17026/dans-zth-dgam

nr	code	site name	site type	n	n det.	date
1	PHW	Tiel-Passewaaijse Hogeweg	rural	16933	6355	LIA to LR
2	OTW	Tiel-Oude Tielseweg	rural	11414	3663	ER to LR
3	HGM	Geldermalsen-Hondsgemet	rural	12011	3660	LIA to LR
4	KEW	Kesteren-De Woerd	rural	8510	3307	ER to MR
5	WDH	Wijk bij Duurstede-De Horden	rural	3658	2883	ER to MR
6	WDG2	Wijk bij Duurstede-De Geer 2	rural	1876	767	Late Roman
7	ZLT	Zaltbommel-De Wildeman sites A, B and C	rural	2963	1733	A.D. 75-200
8	H8A	Houten-Overdam (8A)	rural	1183	998	MR
9	HTL	Houten-Tiellandt	rural	2343	1784	Roman
10	H14	Houten-Schalkwijkseweg (14)	rural	7308	2295	LIA/ER [97]
11	HHD	Houten-Hofstad Diepriool	rural	494	197	ER to MR
12	H21	Houten-Binnenweg (21)	rural	580	485	LR/Early MA
13	HDK	Houten-Doornkade	rural	2671	1403	LIA – A.D. 150
14	TMK	Tiel-Medel Krommewei	rural	269	157	late 1st-2nd cent. A.D.
15	ME6	Tiel-Medel site 6	rural	981	381	ER to LR
16	R&O	Geldermalsen-Rijs en Ooyen	rural	471	167	LIA/ER
17	HLZ	Huissen-Loostraat Zuid sites A and D	rural	2125	741	ER to MR
18	HLR	Huissen-Loovelden Het Riet	rural	540	326	2nd/3rd cent. A.D.
19	HLS	Huissen-Loovelden Riolering	rural	43	36	2nd cent. A.D.
20	BRM	Brakel-Molenkampseweg	rural	796	427	2nd/3rd cent. A.D.
21	HEU	Heteren-Uilenburg	rural	922	506	1st/2nd cent. A.D.
22	ARS	Arnhem-Schuytgraaf	rural [98]	6673	3211	ER to LR
23	ARS7	Arnhem-Schuytgraaf 7	rural	1023	631	ER to MR
24	ARSI	Arnhem-Schuytgraaf Infrastructure	rural	141	89	1st/2nd cent. A.D.
25	DRW	Druten-Wilhelminastraat	rural (villa?)	600	230	A.D. 150-250
26	DRD	Druten-Deest	rural	2427	929	A.D. 40-125
27	EWK	Ewijk-Keizershoeve	rural (villa)	1114	607	ER to MR
28	ILD	IJsselstein-Lage Dijk	rural	5270	763	ER to MR
29	CUL	Culemborg-Lanxmeer	rural	263	126	A.D. 50-150
30	OVB	Oosterhout-Van Boetzelaerstraat	rural	2035	459	ER to MR
31	LEP	Lent-Petuniastraat	rural (villa?)	402	59	1st cent. A.D.
32	LES	Lent-Steltsestraat	rural (villa?)	368	136	ER to MR
33	LR46S	Utrecht-LR46 Settlement	rural	5706	1162	A.D. 15-125
34	LR35	Utrecht-LR35 (Oudenrijnseweg)	rural	668	273	A.D. 40-80
35	LR57	Utrecht-LR57 (De Meern-Burgemeester Middelweerdbaan)	rural	303	140	first half 1st cent. A.D.
36	LR41-42	Utrecht-LR41-42 (Hogeweide)	rural	5016	2034	25 B.C. – A.D. 50
37	LR60	Utrecht-LR60	rural	726	389	A.D. 0-100
38	EMW	Elst-Merm Wolfhoeksestraat	rural	218	79	A.D. 150-300
39	ODS	Odijk-Singel West/Schoudermantel	rural	701	701	LR/Early MA
40	DRK	Druten-Klepperhei	rural (villa)	2516	1749	LIA – A.D. 200

97 According to Vos (2009, 158-159), habitation continued into the 2nd and perhaps 3rd century A.D.

98 Classification is uncertain, due to the lack of information about this site.

41	HLL	Heteren-Het Lage Land	rural	600	487	LIA? – A.D. 150
42	EDW	Ewijk-De Woerdjes	rural	3394	2271	LIA – A.D. 200
43	IHW	Ingen-Het Woud	rural	292	119	MR
44	ZOS	Zoelen-Scharenburg	rural	353	126	1st-2nd cent. A.D.
45	VLEN	Utrecht-Wachttoren Gemeentewerf	rural	262	183	2nd-3rd cent. A.D.
46	LR31	Utrecht-LR31 (Zandweg)	military	1281	301	A.D. 40-70
47	LR39	Utrecht-LR39 (De Balije)	military	817	68	A.D. 40-80
48	NTP	Nijmegen-Trajanusplein [99]	military	558	276	A.D. 10-20
49	NAK	Nijmegen Augustean camp (Koopman)	military	2014	642	19-12 B.C.
50	NAT	Nijmegen Augustean camp (Thijssen)	military	368	188	19-12 B.C.
51	NKP	Nijmegen-Kops Plateau	military	15728	3857	12 B.C. – A.D. 70
52	NCAS	Nijmegen-Castra	military	2782	1497	A.D. 70-120
53	NCT	Nijmegen-Castra (Thijssen)	military	671	402	A.D. 70-120
54	MEI	Meinerswijk	military	140	122	A.D. 10-250
55	WDG1	Wijk bij Duurstede-De Geer 1	military?	742	292	A.D. 150-270
56	NIV	Nijmegen-Valkhof	military	1947	1558	LR
57	NCL	Nijmegen-Canabae (Lauwerier)	urban/military	3093	1951	A.D. 70-120
58	NCW	Nijmegen-Canabae (Whittaker)	urban/military	3070	1612	A.D. 70-130
59	NCC	Nijmegen-Canabae (Canisiuscollege, Robeerst)	urban/military	4238	3535	A.D. 70-120
60	NSS	Nijmegen-Canabae (Schippersinternaat)	urban/military	2528	2115	A.D. 70-120
61	KEV	Kesteren-Vicus	urban/military	384	269	A.D. 70 – 3rd cent.
62	LR46V	Utrecht-LR46 Vicus	urban/military	843	192	A.D. 80-225
63	LR58	Utrecht-LR58 Vicus	urban/military	2632	903	ER-MR
64	N1bc	Nijmegen 1bc	urban	1565	854	A.D. 25-70
65	NOB	*Oppidum Batavorum*	urban	2369	1318	A.D. 0-75
66	NMP	Nijmegen-Maasplein (*Ulpia Noviomagus*)	urban	11087	8386	A.D. 70-270
67	NWW	Nijmegen-Weurtseweg (*Ulpia Noviomagus*)	urban	7206	2197	A.D. 65 – 3rd cent.
68	EGK	Elst-Grote Kerk	temple	909	803	LIA – 3rd cent.
69	ESM	Elst-St. Maartensstraat	temple	2241 [100]	1748	40 B.C. –early 3rd cent.
70	EWE	Elst-Westeraam	temple	563	196	0 – late 2nd cent.
71	EMT	Empel-De Werf	temple	2873	2122	LIA – early 3rd cent.
72	FTN	Nijmegen-Fortuna temple	temple	693	693 [101]	2nd cent.
total number of fragments				**192,504**	**87,321**	

Table 2.1. Archaeological sites included in this study. The date refers to the animal bone assemblages; in some cases the site has a wider date. All references to site publications can be found in the descriptions of the individual sites. Abbreviations of dates: LIA: Late Iron Age; ER: Early Roman; MR: Middle Roman; LR: Late Roman; MA: Middle Ages.

[99] Lauwerier`s Nijmegen 1a.

[100] The more than 90,000 fragments of unidentified fragments of mammal from sieved samples have not been counted here.

[101] The number of unidentified fragments is not mentioned in the report. Most of the material consists of bird bones.

type of site	number of assemblages	n identified fragments
rural settlement	40	46,735
rural settlement: *villa*	5	2781
urban	4	12,755
urban/military	7	10,577
military	10	8911
temple	5	5562
total	**71**	**87,321**

Table 2.2. Site classification and number of identified fragments per type of site.

2.2 CLASSIFICATION OF SITES

The site classification used here serves the main research questions of this study. Since these focus on agrarian production and the relation between producer and consumer sites, the distinction between producer and consumer sites is the most important. However, this is a simplification since production and consumption are rarely strictly separated. In this study, the two categories provide a rough system of classification to help us understand animal bone assemblages. Only one type of producer site is recognised: the rural settlement. Although rural settlements differ in size, there are no 'central places' or a clear hierarchy in status of sites. Although the *villa* could be seen as a separate category due to the difference in building style, this type of site is included with the other rural settlements, because it is also mainly a producer site and there is no evidence that agrarian production was different. It is possible that *villae* had a larger scale of production, or more success, allowing the building of a *villa*. Alternatively, their owners may have had better connections than other farmers. Animal bone assemblages from the *villa* sites will of course be investigated for any differences to other rural sites.

Four types of consumption site are distinguished: military, urban/military, urban and temple sites. Military sites include *castella*, the legionary fortress in Nijmegen and the watchtowers in Utrecht-Leidsche Rijn. Although *canabae* and *vici* can be regarded as military, since they depend on the adjacent army camp, they are discussed separately in this study in an urban/military category. Although there is an undeniable relationship with the Roman army, most of the people living in *canabae* and *vici* were civilians, and they may have had a different food supply and consumption pattern than the soldiers in the army camps. Nijmegen is the only proper town in the region, and this limits our data. Considering the large area and long time period of habitation, and the limited area that has been excavated, our information for Nijmegen is fragmentary. Five assemblages from four temples could be included in this study. The assemblage from the Fortuna temple in Nijmegen is not directly comparable to the others, since it consists of burned animal bones. However, it has been included so that all temples can be discussed together. The reasons for including temples, while cemeteries are excluded (see below), are first, that meat from sacrifice may have constituted a substantial amount of meat for consumption, second, that sacrifice may have affected the agrarian economy, and finally, that the taphonomy is more similar to that in the settlement sites.

Unfortunately, not all sites can easily be categorised. Some sites seem to have a 'military' character, for instance the three sites in Huissen, but since there is no unequivocal evidence for a military character,[102] the sites have been included with the rural sites. For one site, Arnhem-Schuytgraaf, no information about the archaeological structures was available, since the publication has not yet appeared. It has been grouped with the rural sites.

[102] The interpretation was mainly based on the presence of *militaria*, but these are found in all rural settlements.

One type of site is not included in this study: cemeteries. Cemeteries represent small-scale 'consumption' with a limited economic impact. The emphasis in cemeteries was on pig (and sheep) and chicken, which seem to have been less important in agrarian production. A second reason for excluding cemeteries is that animal bone assemblages from cemeteries have a very different taphonomical history. Most animal bones have been burned on the pyre, or are included as grave goods. Analysis of animal bones from cemeteries requires a different way of quantifying fragments, since usually associated fragments from one animal are found in a grave. Therefore, the raw species count is not directly comparable with that of a settlement. Furthermore, the assemblages are usually small, and contain little information on age; since the bones are mostly burned, it is also not possible to take measurements. Larger animal bone assemblages from five cemeteries in the region have been published.[103]

Three rural sites for which some zooarchaeological information was available were discarded, since they were considered of too little value to the current project. The assemblage from Elst-Reethsestraat contains animal remains from one pit, for which only a general Roman date was available.[104] Most of the 105 fragments belong to cattle (91 %), and some elements are from the same individual. The site of Lingewaard-Agropark has yielded a small assemblage of 38 identified fragments, dating to the 1st and 2nd centuries.[105] Because of its small size and date – which overlaps the Early and Middle Roman periods – it has not been included. The 2nd-century site of Tiel-Ooijsche Wetering has only yielded 24 identified fragments, and has therefore been discarded.[106]

2.3 SITE BACKGROUND

2.3.1 RURAL SITES

1. Tiel-Passewaaijse Hogeweg

Tiel-Passewaaijse Hogeweg was excavated between 1999 and 2004.[107] The settlement was inhabited continuously from the Late Iron Age to the Late Roman period, and was almost entirely excavated. A detailed chronology of seven phases made it possible to trace the development of the settlement. Three to six houses were inhabited simultaneously. An important feature in the site was a residual channel that carried water until the late 1st century A.D. The Late Iron Age phase is only known through finds and a cluster of graves; no traces of habitation were found. In the Late Iron Age/Early Roman phase, settlement structures are found on both sides of the residual channel (fig. 2.2). In the next phase, the houses become much smaller and have a different orientation. The first larger granary is found in the later 1st century A.D., and granaries increase both in size and number in the early 2nd century. In the late 1st century, the residual channel dried up, and the number of wells to provide water increased. In the 2nd century, an extensive system of ditches was used to enclose the site and drain some of the surrounding land. New types of buildings, such as stables and houses without central posts, also appear in the 2nd century A.D. Only one farmhouse exists in the early 3rd century; a large granary and a stable are found next to the house in an enclosed farmyard. Two Late Roman houses are of a type normally found north of the Rhine. Pottery and brooches also suggest the presence of migrants from the north.

[103] Tiel-Passewaaij, Zaltbommel, Zoelen, Nijmegen-Hatert, and Cuijk-Heeswijkse kampen. Larger is relative, since only 10 to 31 graves with identified animal bones were recorded for these cemeteries. Esser *et al.* 2010; Groot 2008a; 2011a; Lauwerier 1990; Thijssen 1990; Van Dijk 2011b.

[104] Esser 2002.

[105] Kootker 2010. The zooarchaeological study does add two withers heights for horses to the data set.

[106] Van Dijk 2008a.

[107] Heeren 2006; 2009.

Fig. 2.2. Tiel-Passewaaijse Hogeweg in the Late Iron Age/Early Roman period (phase 2) (Groot 2008a, fig. 1.6).

Archaeobotanical research included samples from a burned granary.[108] The granary is very large and dates to the second half of the 2nd century A.D. Cereals found in the samples are emmer wheat (*Triticum dicoccon*),[109] hulled six-row barley (*Hordeum vulgare* var. *vulgare*), oat (*Avena* sp., wild or cultivated) and millet (*Panicum miliaceum,* represented by one grain). The capacity of the granary could hold much more than the cereals needed to feed the population of Tiel-Passewaaijse Hogeweg and forms an indi-

[108] Kooistra/Heeren 2007.

[109] Scientific names of plant species will only be included the first time the plants are mentioned in the text.

cation for surplus production. Apart from the carbonised remains from the granary, ten samples from wells and one pit containing waterlogged macro-remains were analysed.[110] Species present, besides the cereals already mentioned, include Celtic bean (*Vicia faba* var. *minor*), rape (*Brassica rapa*), flax (*Linum usitatissimum)*, celery (*Apium graveolens*), parsnip (*Pastinaca sativa*) and fig (*Ficus carica*). Black henbane (*Hyoscyamus niger*) and catnip (*Nepeta cataria*) may have been used for medicinal purposes. Fruits from blackberry (*Rubus fruticosus*) and elderflower (*Sambucus nigra*) were collected in the wild. A large animal bone assemblage was analysed by the author.[111] Six phases were distinguished: phase 1: 450-175 B.C.; phase 2: 60 B.C. – A.D. 50; phase 3: A.D. 50-140; phase 4: A.D. 140-220; phase 5-6: A.D. 220-270 and phase 7: A.D. 270-350.

2. Tiel-Oude Tielseweg

About half of the site Tiel-Oude Tielseweg was excavated by amateur archaeologists in the 1990s.[112] Although the settlement was inhabited from the Late Iron Age to the Late Roman period, there are gaps in the habitation in the Late Iron Age and between A.D. 170 and 270. Four farmhouses from three different phases were excavated, as well as a number of small outbuildings. Tiel-Oude Tielseweg is situated c. 300 m from Tiel-Passewaaijse Hogeweg. The two sites are regarded as separate settlements, but the use of a common cemetery is an indication that they formed one community. An animal bone assemblage of over 10,000 fragments was analysed by the author.[113] Five phases were distinguished: phase 1: 300-175 B.C.; phase 2: A.D. 25-70; phase 3: A.D. 70-120; phase 4: A.D. 120-170 and phase 5: A.D. 270-350.

3. Geldermalsen-Hondsgemet

The entire settlement os Geldermalsen-Hondsgemet was excavated in 2005.[114] The site was inhabited continuously from the Late Iron Age until the Late Roman period. Two to four houses were inhabited simultaneously. The earliest features are found on both banks of the residual channel and consist of three houses, a large number of small granaries, ditches and pits.[115] Hoofprints of cattle found on the edge of the channel suggest that cattle were led here to drink. In the Late Iron Age/Early Roman phase, the houses were oriented on the residual channel, and confined to the western bank. Two or three houses existed at the same time. Small granaries were located close to the farmhouses. A system of ditches was laid out in the later 1st century A.D. to enclose farmyards and arable fields. In this period, one farmhouse differentiates itself from the other houses by its large size, enclosure ditches with a clearly demarcated entrance, and the number and nature of finds, including an exclusive bronze *phalera*. Part of the enclosed area lacks structures and may have been used for arable farming, taking advantage of the more fertile soil here that was a result of accumulating refuse and manure from the stabled cattle. The number of granaries is much smaller than in previous periods, and it is assumed that crops were now stored in the farmhouses. In the early 2nd century, the layout of the settlement changes again: the settlement was reorganised from separate farmyards into a larger, coherent whole (fig. 2.3). With the residual channel dried up, the large system of ditches dug in this period served to bring water to the settlement. Wine barrels were used in the construction of two wells. Only one or two farmhouses date to the Late Roman period. Metal finds suggest that migrants from north of the Rhine inhabited the settlement in this period.

Archaeobotanical research was carried out on wood, macro-remains and pollen.[116] The uniformity of one-to-two-year-old willow stems indicates management of willow woodland. Twenty samples

110 Groot/Kooistra 2009; Fokma 2005.

111 Groot 2008a.

112 Heeren 2009; Verhelst 2001.

113 Groot 2008a.

114 Van Renswoude/Van Kerckhove 2009.

115 Van Renswoude 2009a; 2009b.

116 Kooistra 2009a.

Fig. 2.3. Geldermalsen-Hondsgemet in the Middle Roman period (phase 4)
(Groot 2011b, fig. 8; Illustration Jan van Renswoude, VUhbs).

were analysed for macro-remains. Cereals found for the Late Iron Age are hulled six-row barley, emmer wheat and cultivated oat (*Avena sativa*). The presence of flax seeds makes it likely that flax was also cultivated locally. Apart from cereals, rape was present in phase 2, as well as wild teasel (*Dipsacus fullonum*). For phase 3, millet was found in addition to the other cereals; other plants found were Celtic bean, rape, gold-of-pleasure (*Camelina sativa*), black henbane, dewberry (*Rubus caesius*) and elderflower. The fruits were not cultivated, but collected in the wild. Cultivated plants found for phase 4 are oat, hulled barley, emmer wheat, possibly rye (cf. *Secale cereale*), Celtic bean, beet (*Beta vulgaris*), dill (*Anethum graveolens*), opium poppy (*Papaver somniverum*) and wild teasel. Dewberry and sloe (*Prunus spinosa*) were fruits collected in the environment surrounding the settlement. The large and well-preserved animal bone assemblage was analysed by the author.[117] Five phases were distinguished: phase 1: 120-50 B.C.; phase 2: 50 B.C. – A.D. 50; phase 3: A.D. 50-120; phase 4: A.D. 120-270 and phase 5: A.D. 270-425.

[117] Groot 2009a.

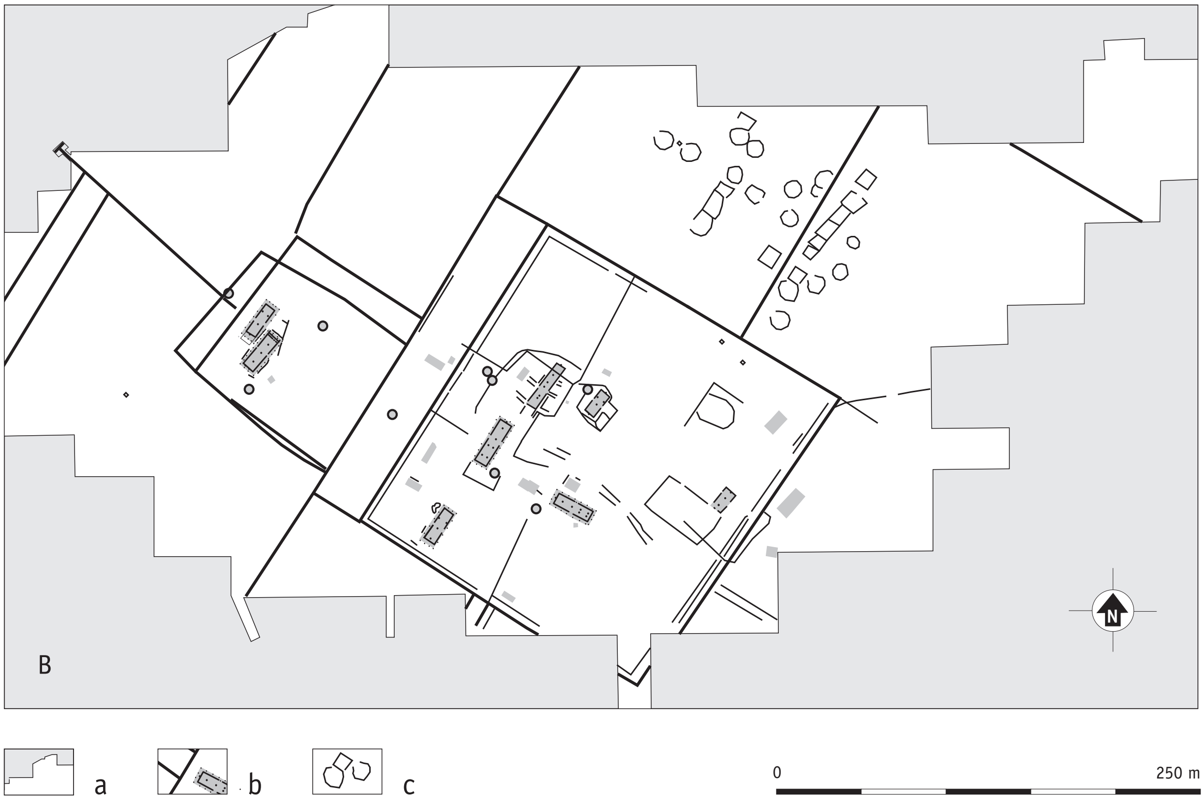

Fig. 2.4. Wijk bij Duurstede-De Horden in the period A.D. 100-150 (Groot *et al*. 2009, fig. 2B).

4. Kesteren-De Woerd

Kesteren-De Woerd is located c. 1.5 km south of the probable *castellum* of Kesteren (*Carvo*). Both *castellum* and *vicus* have been eroded by the Rhine, so little or nothing is known about these sites. Between 1998 and 2000, excavations were carried out at this site before the construction of a new railway.[118] The excavated area follows the intended railway line, and covers a long, narrow strip (c. 400 x 20-40 m). The excavated area coincides roughly with the northern quarter of a rural settlement. Habitation starts at the beginning of the 1st century A.D. and is continuous until c. 270. Five habitation phases are recognised: phase a: A.D. 1-40/50; phase b: A.D. 40/50-70/80; phase c: A.D. 70/80-110/130; phase d: A.D. 110/130-150/170 and phase e: A.D. 150/170-270.[119] Excavated features include two houses, a number of granaries, wells, ditches and pits and an outbuilding that could be a stable (dimensions 4.5 x 8 m). Archaeobotanical analysis of macro-remains has shown that several types of crop were consumed and probably grown.[120] For the Early Roman period (a-b), remains were found of barley, emmer wheat, millet, oat, Celtic bean, pea (*Pisum sativum*), flax or linseed and rape. For the Middle Roman period (c-e), the crops present are barley, emmer wheat, millet, oat, Celtic bean, pea, gold-of-pleasure, flax or linseed, rape, coriander (*Coriandrum sativum*), damson (*Prunus domestica* subsp. *insititia*), beet, walnut (*Juglans regia*), black henbane, and common vervain (*Verbena officinalis*). The last two are possibly medicinal plants. The animal bone assemblage contains both hand-collected fragments and fragments from sieved samples.[121] All hand-collected bones from features were identified and analysed, which resulted in a total of 8075 fragments from the Roman period. The selection of 133 sieved samples for analysis was based on a clear date and interesting contents.

118 Sier/Koot 2001.

119 Siemons 2001.

120 Kooistra/Van Haaster 2001, 301-310.

121 Zeiler 2001.

5. Wijk bij Duurstede-De Horden

Wijk bij Duurstede-De Horden was excavated between 1977 and 1987. A recent study describes the development of the settlement, the house structures, and the organisation of the surrounding landscape.[122] The settlement was inhabited from the Late Iron Age until c. A.D. 200. Habitation at Wijk bij Duurstede-De Horden consisted of four to six farmhouses at any one time (fig. 2.4). Important developments are the presence of some substantial granaries in the Early Roman period, an early reorganisation of the site using rectangular enclosures, and the early presence of a new type of house, without central posts. A large study was devoted to the botanical remains from De Horden, with 309 samples analysed containing around 47,500 carbonised seeds.[123] Barley, emmer and oat were the most common cereals, but millet, spelt wheat (*Triticum spelta*, one glume base) and bread wheat (*Triticum aestivum*, three grains, identification not entirely certain) were also found. The last two may have been imported, together with lentil (*Lens culinaris*, one lentil found). 'Roman' herbs found at De Horden are celery, dill and coriander. While the bulk of the material seems to consist of secondary depositions, two samples could directly be linked to storage of cereals and hay. Analysis suggests that barley and emmer wheat were grown in separate fields, that hay was harvested at the earliest in June, from meadows located on the transition between flood basin and stream ridge, and that livestock fodder consisted of a combination of hay, uncleaned cereals and weeds. The waterlogged remains provide no evidence for human activities. Some further interesting conclusions were drawn from the archaeobotanical analysis. Earlier samples are rich in cereals, while later samples contain more grassland plants. Harvesting hay became important after A.D. 70, whether as a commodity for trade or to feed to the settlement's own livestock. The animal bones were analysed by Laarman.[124] Over 3,500 animal bones date to the Late Iron Age or Roman period. With the exception of the fill of one Middle Roman well, all fragments were collected by hand.

6. Wijk bij Duurstede-De Geer

De Geer is located north of De Horden, at a strategic location: the branching of the river Rhine. This site was excavated in the early 1990s. The settlement was badly disturbed, and no complete house plans were recovered. Finds were collected from wells, pits and ditches. Van Es mentions the intriguing possibility that the two settlements De Horden and De Geer had different agrarian functions, but gives no further explanation.[125] In 2010, analysis of the archaeological structures and some of the finds was started within the framework of Odyssee – a funding scheme of the Netherlands Organisation for Scientific Research to analyse and publish old excavations.[126] The animal bone assemblage consists mainly of fragments collected from wells dating to the Middle (A.D. 150-270) and Late Roman periods.[127] Preservation is excellent. During the analysis of the archaeological structures and finds, it was concluded that the Middle Roman phase represents a military site. The animal bones from this phase will therefore be discussed as a consumer assemblage, under site number 55. In the Late Roman period, habitation is similar to that in Late Roman Tiel-Passewaaijse Hogeweg, although De Geer was a larger settlement, with two to five contemporary houses.[128]

7. Zaltbommel-De Wildeman

At this location, four archaeological sites were excavated in 2005-2007: three settlements and a cemetery. The settlements all date roughly to the same period: A.D. 75-200.[129] At site A, there is also habitation in the Early Roman period (A.D. 0-50). Two house plans were excavated at site A, both

[122] Vos 2009.

[123] Lange 1990.

[124] Laarman 1996b.

[125] Van Es 1994, 232.

[126] Heeren in prep.

[127] Bekkema *et al.* 2011.

[128] Heeren in prep.

[129] Veldman/Blom 2010.

dating to the Early Roman phase. After a short period of inactivity, probably due to flooding, there are plenty of features from the Middle Roman period, but no house plans. The excavation report refers to an 'agrarian zone', since the features present are granaries and small enclosures. It seems reasonable to assume that a farm is located not far from this zone, since granaries are often found near farmhouses. At site B, two house plans were excavated, dating to the same period (A.D. 75-200). Other excavated features are six granaries, three of which are Roman in style (with three or four parallel foundation ditches as opposed to four or five postholes), and a well. The site was not excavated in full, and there may have been one or two more houses in the settlement. Interesting finds include high amounts of briquettage potsherds from ditches near House 1. At Site C, ditches, granaries (both ordinary and Roman-style) and pits were excavated, but no farmhouses. The excavated part of the site was probably on the edge of the habitation. Site C can be dated slightly earlier than site B: A.D. 50-150. Analysis of botanical macro-remains found evidence for emmer wheat, barley, oat and beet at all three sites.[130] At site A, coriander, flax and poppy were also present, while site B provided remains of spelt wheat, dill and rape. At site C, blackberry was found, as well as pollen from rye. An interesting find from site C consists of seeds of a weed that is exclusively associated with flax, found in a steep water pit. This suggests that the pits were used to rot flax, which is necessary to extract the fibres. Assemblages of animal bones from all three sites were analysed.[131]

8. Houten-Overdam (terrain 8A, Houten-Loerik)

Houten-Overdam or terrain 8A is one of the few completely excavated settlements in the micro-region of Houten.[132] The site is located on the Houten stream ridge. The river was no longer active here, but there were three water-carrying residual channels. Excavations took place in 1997 and 1998, and uncovered evidence of habitation and a system of ditches. Five habitation phases could be recognised. Phases 1 (A.D. 1-50) and 2 (A.D. 40-70) cover the Early Roman period. Two farmhouses and some outbuildings date to phase 1. All pottery from this phase is handmade. At least two farmhouses, one of which is very large, were dated to phase 2. Boundary ditches surrounded the settlement in this phase. Three more phases are dated to the Middle Roman period. In phase 3 (A.D. 70-100), the system of ditches was continued and extended. The large building from phase 2 was still in use. In phase 4 (A.D. 100-150), a new boundary ditch was dug, and ditches were extended into the surrounding land. One main building was in use. Phase 5 (A.D. 150-200) also had one main building. The settlement terrain was extended in this phase. Only the animal bone assemblage dating to the Middle Roman period (n=670) is included in this study, since the one dating to the Early Roman period is very small.[133]

9. Houten-Tiellandt

This site was excavated in the 1980s. It was seen as an extremely promising site, but unfortunately most of the information on the chronology and archaeological structures has never been published.

Excavations uncovered several farmhouses from the Roman period, but distinction between the Early, Middle and Late Roman periods is not possible in the present state of research. Several remarkable discoveries were made at this site.[134] First, it has an unusually high percentage of imported pottery for a rural settlement, when compared to other sites in Houten. Also, there are some clear indications for contacts with the army, such as a samian sherd with graffito and stamps on tiles (COHIFLA, cohors 1 Flavia, stationed in Fectio c. A.D. 80-100; LEGXV, 15th legion, stationed in pre-Flavian Xanten; tiles were transported as road building material in the Flavian period). A Roman-style granary was

130 Van Haaster 2010.

131 Esser *et al.* 2010

132 Vos 2009, 148-154; 2000.

133 De Vries/Laarman 2000.

134 Vos 2009, 137-138.

found next to a farmhouse, and dated to the first half of the 2nd century A.D. Finally, wine barrels were used in the construction of wells.

For the archaeobotanical study, samples were taken from the fill of wells and deep pits.[135] Most Roman samples could not be dated more precisely. There are two exceptions. First, four pits and a ditch contained 1st-century threshing waste from wild and cultivated oat, hulled barley and emmer wheat. Second, a rectangular pit contained a layer of charred grain, which was radiocarbon dated to A.D. 250-350. 85 % of the cereals are emmer wheat, 14 % cultivated oat, and 1 % hulled barley. The proportion of cereal grains, chaff and wild plants indicates that this was a batch of threshed grain, ready for sowing or consumption. The proportions of the cereals suggest crop rotation, while the wild plants indicate the inclusion of a fallow period. Other plants encountered in Roman samples include Celtic bean, flax, gold-of-pleasure, poppy, rape, walnut, beet and dill. The archaeobotanical study, in combination with the analysis of insect remains, indicates that livestock was grazed on fallow fields. Although the animal bone assemblage was analysed,[136] this covers the entire Roman period (division into different periods was impossible), so the results are of limited use. At the time the results were published, the assemblage was considered remarkable for the high percentage of horse bones. Now, this seems rather low (14 %). A special find consists of a pit with the butchered remains of a mare.

10. Houten-Schalkwijkseweg (terrain 14)

Terrain 14 is situated on the Houten stream ridge, with a residual channel on the southern side of the site.[137] The western edge of the site was excavated in 2000.[138] Evidence was found for habitation in the Late Iron Age and Early Roman period: ditches, rows of stakes, postholes, pits, one well, two skeletons of cows and a farmhouse. The farmhouse was dated to the Early Roman period by the excavators, but according to Vos, at its earliest it is Flavian.[139] Twenty small outbuildings, mostly 4-to-6-post granaries, were located along the edges of the channel. One larger granary was present, and contained burned emmer wheat. A large amount of handmade pottery was also found here. Some Roman pottery forms and metal finds suggest an early date. However, this does not mean that there was no later habitation, and this is indeed suggested by other finds. A large phosphate stain suggests long and intensive occupation. It is possible that there was a stone building elsewhere on the site. A large animal bone assemblage (n=7308) from this site has been analysed.[140] Since is not clear whether the date range for this assemblage should be widened, the date of the original publication of Late Iron Age/Early Roman period has been followed.

11. Houten-Hofstad Diepriool (terrain 16)

Terrain 16 is also located on the Houten stream ridge, c. 500 m from Houten-Schalkwijkseweg and about 1 km from Houten-Binnenweg and Houten-Overdam. In 2004, two narrow trenches (about 460 m apart) were dug through an archaeological monument, because of the construction of a sewer.[141] The total length was 165 m, with a width of c. 5 m. The archaeologists mostly encountered fill layers of a residual channel, but some features were cut into these layers and the bank of the channel. In the Middle Roman period, habitation was probably located on the western bank, since the finds are concentrated on this side of the channel. The lack of houses and granaries is due to the small scale of the excavation. The analysis of botanical macro-remains has revealed that barley was grown locally in the Iron Age and Roman period.[142] Emmer wheat was definitely grown locally in the Iron Age, but this could not be proven for the Roman period, although it was certainly present. Other Iron Age

[135] Kooistra 1996, 298-329.
[136] Laarman 1996a.
[137] Vos 2009, 156.
[138] Krist *et al.* 2001.
[139] Vos 2009, 158-159.
[140] Buitenhuis 2002.
[141] Schurmans 2005.
[142] Hänninen 2005a.

crops were possibly oat, gold-of-pleasure, rape and flax or linseed. Linseed or flax was grown locally in the Roman period. Interesting finds from the Roman period are remains of dill and celery. The presence of narrow-fruited corn salad (*Valerianella dentata*), a weed which grows on chalky soils (the nearest are in Zuid-Limburg) indicates that cereals were imported to this site in the Roman period. The small animal bone assemblage, with 91 identified fragments, is dated to the Early and Middle Roman period.[143]

12. Houten-Binnenweg (terrain 21)

Habitation remains from the Middle and Late Iron Age at this site include farmhouses ('posthole swarms'), granaries, pits and wells.[144] Pottery from the Early and Middle Roman period is nearly absent, with only 2 % of the total fragments. Recent disturbance of the area may be responsible. In the Late Roman period, this was the periphery of a settlement. No clear structures from this period have been found. The animal bone assemblage dates to the Iron Age, Late Roman/early medieval and Carolingian periods.[145]

13. Houten-Doornkade

Part of an extensive site, located on the northern bank of a residual channel, was excavated in the early 1980s, when plans of farmhouses, granaries and ditches were found.[146] Two habitation phases can be distinguished: Late Iron Age/Early Roman and Middle Roman. Three farmhouses date to the Early Roman period, as well as a small building that was perhaps a stable. Two farmhouses, five outbuildings and an extensive system of ditches date to the period A.D. 70-150. Archaeobotanical analysis identified flax, black henbane, common corncockle (*Agrostemma githago*) and white lace flower (*Orlaya grandiflora*).[147] The last two are weeds associated with loess soils, and could indicate imported cereals. The animal bones from the northern half of the settlement have been analysed.[148] Most of the animal bones date to the period A.D. 50-150. Skeletal elements, age and measurements are not provided per phase, so this severely limits the usefulness of the data.

14. Tiel-Medel Krommewei

Excavations carried out in 2006 revealed ditches, pits and postholes.[149] One ditch was interpreted as part of an enclosure ditch. The excavated area is probably part of the periphery of a settlement. Finds date from the late 1st to the first half of the 2nd century. Eight botanical samples were analysed, and contained remains of cereals (barley, emmer wheat, oat and millet), pulses (Celtic bean and common vetch (*Vicia sativa*)), oil crops (gold-of-pleasure) and wild fruits (elderberry).[150] The animal bone assemblage from Tiel-Medel Krommewei consists of 157 identified fragments.[151]

15. Tiel-Medel site 6

Tiel-Medel site 6 is located c. 750 m from Tiel-Medel Krommewei. Preliminary excavations took place in 2002, followed by full-scale excavation of part of the site in 2003.[152] Habitation was concentrated on a stream ridge with residual channels. Excavation took place in the periphery of the site; the centre was destroyed in the 20th century by the construction of the Amsterdam-Rhine channel. Habitation seems to have been continuous throughout the Roman period. The start of habitation can possibly be dated in the Late Iron Age, but certainly at the start of the Roman period. Two farmhouses were exca-

143 Groot 2005a.
144 Vos 2009, 143-145.
145 De Vries/Laarman 2001.
146 Vos 2009, 121-127.
147 Hogestijn 1984.
148 Taayke 1984.
149 Blom/Williams 2008.
150 Van der Meer 2008.
151 Van Dijk 2008a.
152 Heeren 2005.

vated, one dating to A.D. 10-70 (House 1) and the other to A.D. 90-150 (House 2). Granaries were found close to each house. House 1 was surrounded by ditches, demarcating a farmyard. Features from the Late Roman period are limited to a ditch and several pits. Important finds from the site include the early presence of a relatively high percentage of high-quality imported pottery and an oil lamp (associated with House 1). A connection with the Roman army seems a likely explanation, especially when the find of a pommel dating to before A.D. 40 is taken into consideration. More *militaria* were found at the site: a silver brooch from the Noric-Pannonian region, the tip of a *pilum*, and horse gear dating to the 2nd century. High numbers of tile fragments suggest that at least one building from the period A.D. 150-200 had a tiled roof. The early presence of a veteran (A.D. 10-40) could explain the high-quality pottery and early coins. Botanical macro-remains show that barley was grown locally, and that oat, millet and emmer wheat were consumed if not produced at the site. A coriander seed was present in a Late Roman sample.[153] A total of 981 animal bone fragments was analysed – with 39 % identified to species –, from three different phases covering the entire Roman period.[154]

16. Geldermalsen-Rijs en Ooyen

Excavations were carried out in 2001 in the periphery of the site, at the edge of a residual channel.[155] Features dating to the first half of the Late Iron Age (250-120 B.C.) were found: a granary, postholes and a pit. Most features could not be dated more accurately than the Late Iron Age/Roman period. Two houses could be given a finer date, House 1 between 25 B.C. and A.D. 25, and House 2 between A.D. 1 and 70. Finds of coins and metal could be dated to the Late Roman period. Five fragments of horse gear dating to the Early and Middle Roman period were found. Several botanical samples from the Early Roman period were analysed, but only yielded a few fragments of crops.[156] The animal bone assemblage dates to 120 B.C. – A.D. 70.[157] 471 fragments were analysed, of which 167 were identified to species. The assemblage is highly fragmented, but well-preserved.

17. Huissen-Loostraat Zuid

The two settlements (site A and site D) at this location were partly excavated in 2005.[158] The sites are situated on the southern levee of the Meinerswijk stream ridge. To the south of the sites are flood basins. The Meinerswijk stream ridge probably functioned as the northern border of the Roman Empire until its end phase in A.D. 200. The exact location of the main river channel is not known, but was probably about 1 km to the east of the sites. Two long trenches provided a cross-section through the settlements. Habitation in site A can be dated to two separate phases: A.D. 25-75 and A.D. 150-260. No structures were recognised. A rectangular ditch system dating to the second half of the 2nd century (with ditches with a V-shaped profile) could point to a military influence, if not the actual presence of soldiers at the site. Because of the close proximity to the border and several *castella* (Meinerswijk, Huissen-Hazeberg and Loowaard), this is not unlikely. Habitation in site D starts at the same time as that in site A, but is continuous until at least the end of the 2nd century. During the excavations, part of a house plan and two granaries were discovered. In the northern periphery of site D, a road (with parallel ditches) was found, which is probably the *limes* road. Finds from the two sites indicate close contacts with the army. Finds from the 1st century are mostly civilian, but some of the 2nd-century finds have a military character (such as brooches and a double V-shaped ditch). *Militaria* dating to the 2nd and 3rd century are present in site A, which is a period when these finds are scarcer in rural settlements. A special find from site D is a double hoe with an inscription, which was owned

153 Van Beurden 2005.
154 Groot 2005b.
155 Verhelst 2002.
156 Van Haaster/Van Rijn 2002.
157 Groot 2002.
158 Schurmans 2008.

by a soldier. This and several other *militaria* can be dated to the late 1st or early 2nd century.[159] The coin spectrum shows a contrary development: with coins typical for money circulation in military contexts in the 1st century, while no relation could be established between coins from the 2nd and 3rd centuries and the army. However, this can be explained by the lack of typical 'military' coins for this period.[160] A fragment of a leather shoe shows a typical Roman construction; this type of shoe was made by a specialised shoemaker, but was used both by the civilian and military community.[161] Due to the lack of structures with a clear military nature, the sites have been regarded as rural sites in this study.

Two samples were examined for botanical macro-remains.[162] The sample from a ditch in site A (dated A.D. 200-230) contained oat, barley, emmer wheat, possibly rye and bread wheat, flax or linseed (for which the local origin could be determined) and fig seeds. The sample from a well in site D (dated A.D. 50-260) contained oat, barley, millet, emmer wheat, spelt wheat, flax and possibly pea. The presence of the weed white lace flower in another sample from site D indicates that cereals were imported from a different region. The animal bone assemblage from site A, with 412 identified fragments, dates to the period A.D. 200-260.[163] Most of the animal bones from site D that were analysed date to A.D. 40-120; 334 fragments were identified to species.

18/19. Huissen-Loovelden Het Riet and Huissen-Loovelden Riolering

In 2008, excavations were carried out in the southwestern periphery of a settlement dating to the 2nd and 3rd centuries A.D. This excavation is located only 25 m from Huissen-Loostraat Zuid site D, and clearly part of the same settlement. The excavated features include the boundary ditch, other ditches, small granaries, wells and pits, but no house plans.[164] There are several indications that this is not an 'ordinary' rural settlement. First, the shape of some of the ditches has a military look: V-shaped and sometimes even with an 'ankle breaker' at the bottom. Next, the peak in early Severan coins (A.D. 195-205) can be related to the increase in soldiers' pay, and must be related to the military.[165] Roessingh and Blom write that the settlement started after the mid-1st century, when the *limes* was laid out, probably after A.D. 70. The site does not look like a *vicus*, although the authors rightly say that we know little about what *vici* in this region are supposed to look like. They believe it may have been a *statio*, a stopping place along the *limes* road, where travellers may have found a bed and a change of horse.[166] Archaeobotanical analysis shows that barley was certainly grown locally; this cannot be proven for the other cereals emmer wheat, bread wheat and oat.[167] Other plants of which remains have been found are flax, coriander, walnut and juniper (*Juniperus communis*). Metal finds such as an adze-hammer, scythe and ploughshare suggest craft and agrarian activities, while a sliding weight scale indicates trading. Because of the uncertainty of the nature of the site and the evidence for agrarian activities, Huissen-Loovelden Het Riet has been classified as a rural site here. The small animal bone assemblage from this site has a later date than that of site D.[168]

Huissen Loovelden-Riolering refers to an archaeological supervision of the construction of a sewer. The trenches were dug directly east of Huissen-Loovelden-Het Riet.[169] No undisturbed archaeological features were found, but a very small animal bone assemblage was collected. It is included in this study because it is complementary to the larger assemblages from Huissen-Loovelden Het Riet and Huissen-Loostraat Zuid site D. The animal bones date to the 2nd century A.D.[170]

159 Van Renswoude 2008a, 82, 84.
160 Kemmers 2008, 94.
161 Van Driel-Murray 2008, 102.
162 Hänninen/Kooistra 2008.
163 Groot 2008c.
164 Roessingh/Blom 2011, 23.
165 Kemmers 2011, 89.
166 Roessingh/Blom 2011, 40, 127-128.
167 Van Beurden 2011.
168 Van Dijk 2011a.
169 Roessingh/Blom 2011, 9, 11, 23.
170 Van Dijk 2010a.

20. Brakel-Molenkampseweg
In 2004, an excavation took place in the periphery of a Roman rural settlement. Two hundred archaeological features were found, most of them pits, as well as part of an enclosure ditch. The features date to the late 1st and 2nd centuries A.D.[171] Archaeobotanical analysis indicates the local cultivation of barley and the presence of emmer wheat and (cultivated or wild) oat.[172] The animal bone assemblage contains 427 identified fragments and dates to the 2nd and 3rd centuries A.D.[173]

21. Heteren-Uilenburg
Excavations were carried out in 2009, when a new road was constructed southeast of the village of Heteren.[174] Most of the features uncovered belong to the periphery of a Roman settlement. A remarkable double enclosure ditch can be dated to the late 1st to mid-2nd century A.D. Other features include ditches, pits and waterholes. No farmhouses were found. In the inner of the two enclosure ditches, two horses were buried.[175] Habitation started in the last decades B.C. and the settlement was abandoned in the second half of the 2nd century A.D.[176] Although imported material goods are present, the excavators write that this was a self-sufficient settlement, with no horse breeding for the market. Archaeobotanical analysis revealed the presence of emmer wheat and millet. The emmer wheat was interpreted as threshing waste. Some of the wild plants are typical for arable fields where crops are grown that form their leaves later in the season, such as beets and rape.[177] The animal bone assemblage consists of just under 1000 fragments.[178]

22-24. Arnhem-Schuytgraaf
Arnhem-Schuytgraaf is a so-called VINEX location, an area where large-scale housing development was planned. Several archaeological sites are located in the area, and excavations have taken place by different parties since 1998. The main sites from the Roman period are two settlements (sites 4 and 7) and a cemetery (site 8). The archaeology team of the city Arnhem excavated (parts of) sites 4, 7, 8 and 9 in 1998-2001. The final publication of this excavation has still not appeared, but some information on the archaeological features can be found in a report of a later excavation.[179] A few house plans, granaries, wells and ditches from the Roman period were found in sites 4 and 7. A large animal bone assemblage was analysed, consisting of over 3000 identified fragments.[180] Most of the animal bones date to the Middle Roman period.

In 2003, some of the planned infrastructure for the development made it necessary to excavate a long trench in the periphery of sites 4, 6, 7 and 8.[181] The archaeological features that were encountered date to the 1st and 2nd centuries A.D. Animal bones were collected by hand and include a pig skeleton.[182] Most of the animal bones date to the Roman period.

The core of site 7 was excavated in 2008, after it became clear that it could not be protected.[183] A large number of postholes, pits, wells and ditches were found. Three possible house plans are described, two of which certainly date to the Roman period.[184] Eighteen small granaries date to the Iron Age or Roman period. The ditches are interpreted as part of four different enclosure systems. Botanical samples from five wells and one pit were analysed.[185] Barley was the most common cereal, with mil-

171 Schrijer *et al.* 2005, 5, 6, 20.
172 Hänninen 2005b, 23.
173 Esser 2005.
174 Blom/Roessingh 2010a.
175 Hazen/Roessingh 2010, 51.
176 Blom/Roessingh 2010b.
177 Moolhuizen 2010.
178 Van Dijk 2010b.
179 Roessingh/Blom 2009, 10-12.
180 Esser/Van Dijk 2004.
181 Tuinstra *et al.* 2005.
182 Buitenhuis 2005.
183 Roessingh/Blom 2009, 9.
184 Roessingh 2009.
185 Bos *et al.* 2009.

let, foxtail millet (*Setaria italica*), wheat (*Triticum* sp.) and einkorn (*Triticum monococcum*) also present. Other crops were beet and black mustard (*Brassica nigra*), while elderberries were collected in the wild. Cherries (*Prunus* sp.) may have been cultivated. Black henbane may have been grown as a medicinal plant. The weeds indicate well-manured fields or vegetable plots. An animal bone assemblage – with 631 identified fragments – dating to the Iron Age/Roman period was analysed.[186] Since most of the finds are from features dating to the Early and Middle Roman period, the animal bones are assumed to reflect that period.[187]

25. Druten-Wilhelminastraat
In 2006, an archaeological excavation was carried out in the periphery of the settlement area of the *villa* of Druten-Klepperhei.[188] The core of this settlement was excavated in the 1980s (see site nr 40). The dating of the features and finds from the more recent excavation is between A.D. 150 and 250, which is comparable to Druten-Klepperhei phase III. Excavated features are mostly ditches, postholes and pits; no structures were found. The only cultivated plants found in a botanical sample are barley and oat.[189] A small animal bone assemblage has been analysed.[190]

26. Druten-Deest site 10
Druten-Deest site 10 is situated c. 1.5 km southwest from Druten-Klepperhei (site nr 40). At this location, planned sand extraction would destroy the archaeological sites. In 2002 and 2003, excavations were carried out in a Roman settlement.[191] The size of the excavated area is limited (60 x 65 m) and probably situated in the periphery of a settlement. This was located on or near a sandy crevasse deposit, next to a channel. Features encountered are ditches, pits and postholes; no structures such as farmhouses or granaries were identified. Regular flooding may have made the excavated area unsuitable for habitation, but some activities clearly took place here. The number of finds suggests that habitation cannot be too far away. The pottery mainly dates to the last part of the 1st century A.D., with some material from the early 2nd century. Metal finds (including an iron spearhead and fragments of horse gear) date to A.D. 40-125. The only cultivated crop found in botanical samples is barley.[192] The animal bone assemblage is relatively large considering the size of the excavation, and is well-preserved.[193] Out of a total number of 2427 mammal fragments, 929 fragments were identified.

27. Ewijk-Keizershoeve
This site is located c. 1 km from Ewijk-De Woerdjes (site nr 42).[194] Excavations were carried out at Ewijk-Keizershoeve in 2009, in the area adjacent to a protected monument: the *villa* 'De Grote Aalst'.[195] This *villa* has been known from finds since the 1970s, and is reported to be one of the most luxurious ones of the Dutch River Area. It was built in the late 1st century A.D. and renovated or adapted in the first half of the 2nd century. Phase 1 covers the Early Roman period, from c. A.D. 30 to 80/100. Features dated to this phase are five house plans, five small granaries, six wells and 11 pits.[196] Phase 2 lasts from the beginning of the 2nd century to the second half of the 3rd century. It is contemporary to the *villa*, and characterised by a lot of building debris. A maximum of seven house plans were dated to this phase. The settlement was enclosed by a ditch probably in the second half of the 2nd century. Houses with a 'Roman' signature – a *porticus* – are found from around A.D. 150. A structure directly

186 Van Dijk 2009.
187 Blom/Roessingh 2009, 120.
188 Schurmans 2009.
189 Kooistra 2009b, 41.
190 Groot 2009b.
191 Krist 2003; Nieuwhof 2004.
192 De Roller 2003, 39-40.
193 Buitenhuis 2003; Halici 2004a.
194 Blom *et al.* 2012
195 Blom/Veldman 2012, 13-16.
196 Van der Feijst/Veldman 2012.

related to the *villa* in the centre of the settlement is a drainage sluice built out of tuff stone and roof tiles. Two house plans and three wells date to the Late Roman period.

Analysis of botanical macro-remains has identified the following species: (wild or cultivated) oat, barley, emmer wheat, celery, beet, carrot, parsnip, black mustard or rape, common hop (*Humulus lupulus*), opium poppy, hazelnut (*Corylus avellana*), dewberry, blackberry and elderberry.[197] Pollen was found for many of the same species, and also for rye and dill. There was no evidence for bread or spelt wheat, the cereals that are typical for the southern *villae*. With the exception of opium poppy and perhaps chives (*Allium schoenoprasum*, identification uncertain), the archaeobotanical study suggests that the site had a rural character and was self-sufficient. The animal bones were mainly collected by hand, but some derive from sieved samples.[198] The size of the assemblage is reasonable, with 607 bones identified to species. Since the animal bones were collected in the periphery of the site, it is questionable whether they should be related to the *villa* at the centre.

28. IJsselstein-Lage Dijk

Several excavations took place between 1998 and 2001 to investigate an area that would be disturbed by a future road.[199] The area contained archaeological remains from the Bronze Age, Iron Age and Roman period. The excavated features were difficult to interpret due to the narrow width of the trenches. Part of a house plan was uncovered, which was built around the middle of the 1st century A.D. Other features are three granaries, ditches, wells, pits, a horse burial and lines of posts. Most of the ceramics found at IJsselstein-Lage Dijk can be dated in the 2nd century A.D., with an emphasis in the second half of the century. However, some 1st-century material is also present.[200] Noteworthy is that the ceramics contained a relatively large amount of handmade 'coastal' ware (salt containers). The brooches and coins found at the site all date to the second half of the 1st century and the 2nd century.[201] Archaeobotanical analysis found carbonised remains of oat, barley, emmer wheat, bread wheat and spelt wheat.[202] Barley, emmer wheat and oat are present in the largest numbers. Another important crop was flax. Oat, barley and flax were certainly cultivated locally. Bread and spelt wheat may have been imported. Finally, there is evidence for grassland maintained by grazing. Considering the size of the excavated area, the animal bone assemblage is large: 5270 fragments.[203] However, because the majority was collected by sieving, a large number are small, unidentifiable fragments. Only 7.5 % of the mammal fragments were identified to species.

29. Culemborg-Lanxmeer, site B

A small excavation took place in the periphery of a Roman settlement in 2003.[204] The site is located on the southern levee of a stream ridge. Features found during the excavation include pits, ditches and postholes, but no houses or other structures. Most features date to a short time period around A.D. 100, although a wider date for the site is also given (A.D. 50-150). Analysis of botanical macro-remains has only found evidence for oat.[205] A small animal bone assemblage from the site, of just over a hundred identified fragments, was analysed.[206]

[197] Brijker *et al.* 2012.
[198] Van Dijk 2012.
[199] Bulten 2002.
[200] Bloo/Wiepking 2002, 52-53.
[201] Nooijen/Van der Chijs 2002, 73.
[202] Van Haaster 2002.
[203] Van Dijk 2002.
[204] Huis in 't Veld 2004.
[205] De Roller 2004, 42.
[206] Halici 2004b.

30. Oosterhout-Van Boetzelaerstraat (De Waalsprong site 8)
North of Nijmegen, on the northern bank of the river Waal, is the VINEX location 'De Waalsprong'. Plans for extensive housing development led to large-scale archaeological excavations in the late 1990s. Unfortunately, while data and finds were collected in the field, no funding was available for post-excavation analysis and publication. Some preliminary information on the excavations was published in 2002.[207] The main Roman site in this location is Oosterhout-Van Boetzelaerstraat. This site was inhabited continuously from the Late Iron Age to the mid-3rd century A.D. The settlement was enclosed by ditches in the 1st century A.D., and covered 4.5 hectares. Excavations have also uncovered a cremation cemetery adjacent to the settlement, and a system of field parcelling and drainage ditches. Two separate habitation nuclei can be recognised, but the site shows no evidence for social differentiation. Some of the more remarkable finds from this settlement include a complete Roman sword, three terracotta statuettes of the goddess Cybele and two lions, and some wooden writing tablets. The farmhouses themselves are indigenous in character; there is no evidence for *porticus* houses, which are found in other settlements in the region. A selection of animal bones from Oosterhout-Van Boetzelaerstraat was analysed even before the excavations finished;[208] the rest remains unpublished. The assemblage dates to the Early and Middle Roman period and consists of 2036 fragments, with 459 fragments identified.

31. Lent-Petuniastraat (De Waalsprong site 58)
Only a small number of archaeological features have been excavated at this site.[209] These belong to a Roman settlement close by (De Waalsprong site 34, Lent-Laauwikstraat-Zuid). The only noteworthy feature is a pit with a large number of animal bones, pottery and fragments of a bronze kettle. This location is also close to Lent-Steltstestraat (site nr 32). Both sites are believed to have been part of a *villa* complex, with the main building located in the Azaleastraat. A small animal bone assemblage – with only 59 identified fragments – from this site was analysed.[210]

32. Lent-Steltstestraat A (De Waalsprong site 35)
Only one farmhouse was excavated at this site.[211] The farmhouse was rebuilt several times between the 1st and 3rd century A.D. It is located about 80 m from an active channel. It is likely that the farmhouse was located in the periphery of a settlement. An earlier find of a building with stone foundations in the Azaleastraat (about 200 m from the farmhouse) and finds of wall paintings are an indication for a special character of the site, which was possibly a *villa*. An alternative explanation is that this was a roadside *vicus*.[212] Indications at the site itself for close connections with urban and military Nijmegen are numerous finds of Roman pottery, roof tiles, slate, coins and brooches. A small animal bone assemblage from the site, containing 136 identified fragments, has been analysed.[213]

Utrecht-Leidsche Rijn general
Since 1997, the development of the largest VINEX location of the Netherlands has taken place to the west of Utrecht. This location is called Leidsche Rijn, and covers the stream ridge of the Rhine. Archaeological investigations preceding the building work have uncovered many Roman sites, relating to the Roman border and the frontier zone on the left bank of the river. This has provided a detailed image of the organisation and development of this part of the Lower German *limes*, and given new insight into the infrastructure especially. A section of the *limes* road was discovered in 1997, and fol-

[207] Van den Broeke 2002.
[208] Whittaker 2002.
[209] Van den Broeke 2002, 26.
[210] Whittaker 2002.
[211] Van den Broeke 2002, 23.
[212] Willems/Van Enckevort 2009, 93-94.
[213] Whittaker 2002.

lowed over 3 km. Apart from the *limes* road, watchtowers, part of a *vicus* and indigenous rural sites have been excavated. The settlements in Leidsche Rijn all date to the 1st century A.D. and show no continuity with the Late Iron Age. On the basis of the starting date of the habitation and the presence of pottery that is typical for the northern part of the Netherlands, Langeveld has suggested that new groups, which already had friendly relations with the Romans, were settled here in a policy to consolidate the border region. They may also have played a role in supplying the troops.[214]

33. Utrecht-Leidsche Rijn 46 Settlement

In 2004, excavations took place in the area to the south of *castellum* De Meern.[215] It was expected that part of the *vicus* and the *limes* road would be uncovered, but an unexpected find was a rural settlement in the eastern part of the excavated area.[216] The settlement was situated on the western bank of a residual channel. The Roman features date from the second decade A.D. to c. A.D. 110. An area of about 85 x 20 m was excavated. The only evidence that people lived here was part of a farmhouse from the first phase; later phases revealed ditches and pits but no more houses. Around A.D. 40, the area surrounding the *castellum* was reorganised with a new layout of ditches. Activities later in the 1st century may be related to inhabitants of the *vicus*. The distance from the settlement to the *vicus* was about 100 m. A special find from a water pit suggests that the inhabitants of the Early Roman settlement had a special relationship with the Roman army: the beautifully decorated front piece of a cavalry helmet, which had been deliberately destroyed. One of the inhabitants of the settlement must have served in the Roman army and brought his equipment home.[217]

Archaeobotanical analysis revealed the presence of the cereals barley, emmer wheat, oat (cultivated or wild) and spelt wheat.[218] It is likely that the spelt wheat was cultivated more to the south, which is also suggested by the find of common corncockle. Other plant remains include flax, black mustard, rape and coriander. Coriander is found in 2nd-century rural sites in the region, but has never been encountered before at such an early date outside military sites. Both the spelt wheat and the coriander indicate close contacts with the military. Interestingly, the coriander predates the *castellum*. One more remarkable find concerns pollen from rye. The amount of pollen is too low to suggest local cultivation. In the Early Roman period, rye was only grown by farmers north of the Rhine, and its presence suggests another import. The channel yielded a large number of animal bones, with over a thousand fragments identified to species.[219] The assemblage is dated between A.D. 15 and 125.

34. Utrecht-Leidsche Rijn 35 (Oudenrijnseweg)

Excavations in 2003 and 2004 uncovered archaeological features on the northern bank of a residual channel (fig. 2.5).[220] Features from 25 structures were found: one farmhouse, one larger outbuilding and 23 granaries. Ditches enclosed a farmyard and three areas, two of which were interpreted as livestock enclosures based on the presence of manure in the ditches. The third contained most of the granaries and was seen as an enclosure where the harvest (cereals and flax) was collected and processed. The farmhouse was dated to A.D. 40-80. The find of a fragment of *lorica segmentata* indicates a connection to the army. This site is located about 1 km from *castellum* De Meern, which was constructed in the early 40s. Analysis of the botanical remains has identified emmer wheat, barley, oat, rape and flax.[221] The flax was certainly grown locally. Interpretation of one seed of hop is difficult, since this

[214] Langeveld 2010a, 324-326.
[215] Langeveld *et al.* 2010b.
[216] Weterings 2010.
[217] Langeveld 2010b, 297-299.
[218] Kooistra 2010.
[219] Groot 2010a.
[220] Luksen-IJtsma 2009.
[221] Van Haaster 2009.

Fig. 2.5. Utrecht-LR35: a 1st-century rural settlement (Luksen-IJtsma 2009, fig. 3.6).

plant could have grown naturally in the surroundings of the site. The animal bone assemblage contains 273 identified fragments, and is especially interesting because of the narrow date.[222]

35. Utrecht-Leidsche Rijn 57 (De Meern-Burgemeester Middelweerdbaan)

At this site, excavations uncovered Early Roman features on and around a silted-up residual channel from the Bronze Age.[223] No clear structures were found, but several postholes in a row could be part of a granary. Two wells with a wooden construction were excavated. The large number of features suggests that the core of the settlement was not far away. The site was dated on the basis of pottery to the early part of the 1st century A.D.[224] A small animal bone assemblage – 140 identified fragments – was analysed.[225]

36. Utrecht-Leidsche Rijn 41-42 (Hogeweide)

Remains of Late Iron Age and Early Roman habitation were excavated in 2003 on both banks of a channel.[226] On the eastern bank, granaries, ditches and pits dating to 25 B.C. – A.D. 20 were found, as well as a slightly later hayrick (A.D. 20-50). Features on the western bank include granaries, pits, ditches, a small building, and the probable remains of a farmhouse. One of the granaries had a *horreum*-like plan. The channel was used as a dump, which explains why it yielded most of the finds. The handmade pottery shows some similarities with pottery from the northern Netherlands, which could indicate Chaucian immigrants. Quite a large amount of very early imported Roman pottery (transport

222 Esser 2009a.

223 Meijer 2009a.

224 Stoffels 2009, 136.

225 Meijer 2009b.

226 Den Hartog 2009.

as well as table ware, from the 2nd quarter of the 1st century A.D.) is found at this site, which indicates close connections with the army. Lots of *militaria* and agrarian tools suggest that this was a rural settlement where a veteran from the Roman army lived. Around A.D. 50 when the *limes* was formed several hundred metres from the site, the location was abandoned. The well-preserved animal bone assemblage, containing more than 2000 identified fragments, was mostly collected from the channel, but also contains material from the two banks.[227]

37. Utrecht-Leidsche Rijn 60

Between 2006 and 2008, archaeological research was carried out in eight locations east of De Meern. Utrecht-LR60 is located south of Utrecht-LR46 (site nr 33) and north of Utrecht-LR35 (site nr 34). The aim was to find and investigate the *limes* road.[228] At one location, the fill from a crevasse channel predating the *limes* road provided information on activities on the bank of the channel in the 1st century A.D. Seven layers could be distinguished, as well as several finds concentrations. Concentrations A and B in layers 5 and 6 consist of complete pots and cattle bones rich in meat. These concentrations are interpreted as the remains of ritual meals.[229] SEM and chemical analysis of residues found on potsherds revealed the preparation of a special kind of food, consisting of a combination of animal protein (milk or fish products), plant oils and green parts of plants, but without cereals.[230] Animal bones from the channel were analysed for all layers separately – 389 identified fragments in total.[231] Transport of sheep parts rich in meat away from the site is suggested, with the forelimbs consumed on the site.[232]

38. Elst-Merm Wolfhoeksestraat

In July 2009, a small excavation was carried out in the site Merm-Wolfhoeksestraat near Elst, because the construction of a gas pipeline would disturb the archaeological features.[233] In a trench of 30 x 5 m, a number of pits, ditches and a waterhole were found, together with finds from the Middle Roman period. The features are believed to represent the periphery of the settlement, although the large number of finds suggests that habitation was not far away. Most of the pottery was dated to the period A.D. 150-300.[234] The number of finds of military horsegear was large for the size of the excavation.[235] A small assemblage of animal bones, with less than a hundred identified fragments, was analysed.[236]

39. Odijk-Singel West/Schoudermantel

This site was excavated in 2005.[237] It was mainly inhabited during the Late Iron Age, Late Roman period and Early Middle Ages. In the Roman period, the settlement was located directly on the border of the Empire. A lot of settlement features were excavated, but no house plans were recognised. Seven granaries and a rectangular ditch system date to the Iron Age.[238] Features dated to the Late Roman period consist of a ditch, pits, a well and one posthole. More features were dated to the overlapping Late Roman/Early Medieval period: postholes, pits, ditches, a well and an animal burial. Finds of horse gear from the Middle Roman period in an area demarcated by ditches on two sides are seen as a possible indication that horses were trained at this location.[239] Evidence was found for production of iron in the Late Roman or Early Medieval period, as well as of bronze, lead and perhaps silver.[240]

227 Esser 2009b; Esser/Beerenhout 2006.
228 Weterings/Meijer 2011.
229 Meijer 2011, 122; Weterings/Meijer 2011, 46, 50, 52.
230 Oudemans/Kubiak-Martens 2011.
231 Meijer 2011.
232 Meijer 2011, 122; Weterings/Meijer 2011, 53.
233 De Groot 2013.
234 Van der Linden *et al.* 2013, 76.
235 Verhelst 2013, 103.
236 Groot 2013a.
237 Verhelst/Schurmans 2007.
238 Schurmans 2007.
239 Verhelst 2007, 110, 120.
240 Boreel 2007, 140; Verhelst 2007, 118.

During the analysis of botanical macro-remains, barley, wheat (emmer or spelt), (wild or cultivated) oat and flax were found for the Late Iron Age.[241] For the Late Roman period, the plant species present are barley, emmer wheat, millet, black mustard, rape and gold-of-pleasure (probably as a weed), and hazelnut. For the Late Roman/Early Medieval period, some interesting plants were found: first, corn salad (*Valerianella locusta*, a vegetable that could be cultivated or collected as a wild plant); and second, black henbane, dyer's rocket (*Reseda luteola*) and common vervain, all three medicinal plants and found in one well. The pollen data from Odijk for the Late Roman/Early Medieval period are interesting, because contrary to the general view for the River Area, there is no evidence for regeneration of woodland. Animal bones from this site were analysed by Zeiler.[242] Just over 2000 fragments were selected for analysis, mostly hand-collected material but including some sieved samples.

40. Druten-Klepperhei

This site was excavated in 1974-1978. It is situated on the southern levee of the river Waal, 18 km west of Nijmegen.[243] The settlement consists of different buildings grouped around a rectangular courtyard. Together the buildings form a large farmstead. Building started just after A.D. 70.

The building at the short, west end of the courtyard must have had a central position, not just because of its location, but also because of its size, complex interior layout and association with a stone-built bathhouse. Hulst sees the complex as a *villa* due to the axial layout with two wings. The founding of the *villa* shortly after A.D. 70 may have been prompted by the stationing of *Legio X Gemina* in Nijmegen, but it also fits in with the demands of the growing town of *Ulpia Noviomagus*. Willems and Van Enckevort see Druten-Klepperhei as an attempt to "initiate organized surplus production".

Occupation ended in the beginning of the 3rd century. The animal bones from Druten-Klepperhei were analysed by Lauwerier.[244] He distinguished three phases: Druten I: pre-dating A.D. 75, possibly Late Iron Age; Druten II: A.D. 75-150; and Druten III: A.D. 150-200.

41. Heteren-Het Lage Land

Excavations were carried out at this site in 1968-1970.[245] A complex of ditches in a rectangular pattern (c. 100 m wide) was uncovered, surrounding traces of occupation. A large number of postholes was found at the centre. One farmhouse and a number of small outbuildings could be recognised. The ditches outside the settlement may have served as parcel boundaries of fields or pastures. Van Es has suggested that Heteren-Het Lage Land and Ewijk-De Woerdjes (site nr 42) were central storage facilities for crops, although this interpretation seems based on a lack of recognisable farmhouses rather than a positive identification of granaries.[246] Lauwerier analysed the animal bones from this site, and distinguished two phases: Heteren I, pre-mid-1st century A.D. and Heteren II, mid-1st to mid-2nd century A.D.[247]

42. Ewijk-De Woerdjes

This site was excavated in the 1970s.[248] Habitation from the Iron Age and Roman period was found. Two house plans were found, one of which was dated to the later part of the 2nd century A.D. A rectangle of posts measuring 15 x 6 m was interpreted as a possible storage facility. Outside the inhabited area the terrain is divided by a system of ditches. Van Es suggests the possibility that both Ewijk-De Woerdjes and Heteren-Het Lage Land were storage depots for agricultural products, perhaps in rela-

[241] Kooistra 2007.

[242] Zeiler 2007.

[243] Hulst 1978; 1980; Willems/Van Enckevort 2009, 88-89.

[244] Lauwerier 1988, 95-111.

[245] Van Es 1981, 169; Lauwerier 1988, 90.

[246] Van Es 1981, 169, 230.

[247] Lauwerier 1988, 90-92.

[248] Hulst *et al.* 1973; Hulst/Noordam 1974; 1977a.

tion to a larger estate.[249] The animal bones from Ewijk-De Woerdjes were analysed by Lauwerier.[250] He distinguished two phases: Late Iron Age-Early Roman and the 2nd century A.D.

43. Ingen-Het Woud
At this site, two test trenches were excavated in 2011.[251] Evidence was found for a Late Iron Age to Middle Roman settlement on the southern bank of a residual channel. Features consisted of ditches, pits, postholes and find layers. The *limes* road was probably situated about 400-500 m north of the site. For its small size, the excavation uncovered a large amount of finds, including animal bones. The number of animal bones from the Early Roman period was very small, but a larger animal bone assemblage, with 119 identified fragments, was available for the Middle Roman period.[252]

44. Zoelen-Scharenburg
A Roman settlement and cemetery are located at this site.[253] Excavations in 2007 focused on the settlement and the establishment of the boundaries of the cemetery, while the cemetery was excavated in 2008. The excavation in the settlement took place in the periphery. Granaries, postholes and ditches were found, but no house plans. One interesting find was a concentration of 18 loomweights in a pit. Some evidence was found for ditches outside the settlement area, leading to the residual channel, and structuring the land for agrarian activities. The settlement dates to the 1st and 2nd centuries. Analysis of botanical macro-remains identified oat, barley, emmer wheat and possibly einkorn.[254] One sample was interpreted as waste from winnowing grain. The results of pollen analysis suggest an open landscape. Interesting is the indication that use of the landscape intensified from the 1st to 2nd centuries, with woodland being replaced by arable fields on the higher grounds and grassland in the flood basins. The small animal bone assemblage, with just over 100 fragments identified to species, was divided into two phases, roughly covering the 1st and 2nd centuries respectively.[255]

45. Utrecht-Wachttoren Gemeentewerf (VLEN3)
An excavation was carried out in 2000 and 2001, originally to map the *limes* road. When a round ditch and a concentration of building stone were found, it was suspected that these were the remains of a watchtower, and the excavation was extended.[256] Little was found of the supposed watchtower, but the residual channels of the Heldam stream ridge yielded remains of wooden constructions (a bridge, two jetties and possible sheetpiling) as well as several fyke nets.[257] A large number of finds was also collected from the fills of the channels, indicating habitation in the early 1st and later 2nd/3rd centuries. Although the finds could not confirm the hypothesis of a watchtower, the site was interpreted as a military site, inhabited by a small detachment of soldiers and their families, who were responsible for organising additional food supply to the *castellum* and *vicus* of De Meern.[258] However, it seems that the only reasons to assume a military character for this site are the location close to the *limes* road and the presence of a few *militaria* (arrowhead and spearhead). The ceramics are similar to those from rural sites (although this was also the case for the watchtower in Utrecht-LR31), and *militaria* are also commonly found on rural sites.[259] Moreover, there is evidence for horticulture and extensively grazed grassland,[260] which seems more consistent with a rural site. For this last reason, this site is grouped with the rural settlements, although it is recognised that there are some components that are unusual. These consist

[249] Van Es 1981, 230.
[250] Lauwerier 1988, 92-95.
[251] Verhelst 2012.
[252] Groot 2012a.
[253] Veldman 2011.
[254] Zuidhoff *et al.* 2011.
[255] Van Dijk 2011b.
[256] Dielemans 2013, 9, 12.
[257] Dielemans 2013, 36-38; Van Rijn 2013.
[258] Dielemans 2013, 167-171.
[259] Niemeijer 2013.
[260] Van Haaster 2013.

of the evidence for crafts: textile fabrication and painting, leatherworking and meat processing.[261] Botanical macro-remains included emmer wheat, spelt wheat, barley, poppy and fig. Dyer's rocket and teasel suggest textile production and painting of textiles.[262] Animal bones were mostly found in the channel fills.[263] A small number could be dated to the early 1st century or the second half of the 2nd century, while a much larger number was mixed up and could date either from the 1st century or the later habitation. Fortunately, there is also an assemblage from the 2nd and 3rd century, containing 183 identified fragments.

2.3.2 Military sites

46. Utrecht-Leidsche Rijn 31 (Zandweg)

In 2002, it was necessary to excavate a section touching on the protected *limes* road.[264] Unexpectedly, the remains of two consecutive wooden watchtowers were found. The towers were built on a naturally higher part of the landscape, just to the south of the river. The watchtowers are part of the first phase of the *limes* along the Oude Rijn. They contribute to the image of a strongly guarded transport corridor through an inhospitable landscape. Features dating to the first phase of the watchtower consisted of four postholes, an occupation layer with a hearth, a ditch to collect rain water from the roof, posts of a wattle palisade and a wide V-shaped ditch with remains of five rows of stakes. The main posts were of alder, which is not very strong, and the tower probably only had one upper floor (fig. 2.6). In the second phase, the tower was moved slightly to the northeast and surrounded by two concentric ditches. The main posts were of oak, which suggests that the tower now had two upper floors. Dendrochronology gives a felling date for one of the posts from phase 2 of A.D. 61 or 62. The presence of burned loam indicates that the tower burned down. Most of the finds date to phase 1a. Pottery dates the start of the occupation to the 40s, and the absence of typical Flavian pottery indicates that the watchtower was abandoned before A.D. 70.

The organic remains from the watchtower are well-preserved and provide a rare insight into the provisioning of a small military unit in the Early Roman period. The diet of the soldiers stationed here was a combination of local and supplied foods, as well as a combination of Roman and indigenous foods. Cereals and meat provided the bulk of the diet, and were probably brought from the garrison base. Perhaps this food was not sufficient, and soldiers may have had to gather food locally to supplement their diet. Cereals present at the site are barley, emmer, possibly oat and possibly spelt wheat. Other plants for which remains are found are walnut and elderflower.[265] The animal bone assemblage consists largely (87 %) of remains from sieved samples.[266] The total number of fragments is 2457, including fish remains and molluscs. Considering the narrow time span of the watchtowers and the small number of identified mammal remains, the assemblage was described as one, without taking the different phases into account.

47. Utrecht-Leidsche Rijn 39 (De Balije II)

At this location, several sites have been excavated: two watchtowers, part of the *limes* road, a ship, and ditches, postholes and pits.[267] The second phase of the eastern watchtower was dated by dendrochronology to between A.D. 55 and 62. The western watchtower, dated A.D. 70-80, shows a typical lay-out of four postholes surrounded by a double ditch. The tower was probably dismantled at the end

[261] Dielemans 2013, 167-168; Esser 2013; Van Haaster 2013, 148, 157; Kerkhoven 2013.

[262] Van Haaster 2013.

[263] Esser 2013.

[264] Van der Kamp 2007.

[265] Van Haaster 2007, 162-163.

[266] Esser *et al.* 2007.

[267] Langeveld 2010c; Langeveld *et al.* 2010a.

Fig. 2.6. Watchtower in Utrecht-Leidsche Rijn (LR31) (Kelvin Wilson).

of its life. The presence of burned loam indicates that it burned down, but it is not possible to establish whether this was intentional or accidental. Finds from the watchtowers in Leidsche Rijn indicate close relations with the indigenous population. The pottery assemblage shows more similarities with contemporary rural sites in the region than with military sites. The presence of a sling bullet (found in the Dutch River Area from the mid-Iron Age to the 1st century A.D.) could be an indication for occupation by local troops. A 'Roman' indicator is an *amphora* sherd of a Dressel 20, which was used for olive oil. Although this could be an indication of a more Mediterranean diet, it is equally likely to be a result of secondary use of transport *amphorae*. Only the animal bone assemblage from the western watchtower is large enough to be meaningful.[268] The animal bones (a total of 838 fragments) are both hand-collected and from sieved samples.

Nijmegen general

A large concentration of Roman remains covers the southern bank of the Waal, at the present location of the town of Nijmegen (figs. 2.7 and 2.8).[269] A large military presence can be found from the start of the Roman period and throughout the 1st century. Urban development starts in the early 1st century at the Valkhof (*Oppidum Batavorum*), and moves west to *Ulpia Noviomagus* after the Batavian revolt. A large cemetery separated *Oppidum Batavorum* from the military camps on the Hunerberg. Military presence was concentrated on the Hunerberg, with successive phases of a legionary camp and a smaller

[268] Van Dijk 2010c.

[269] See also paragraph 1.2.

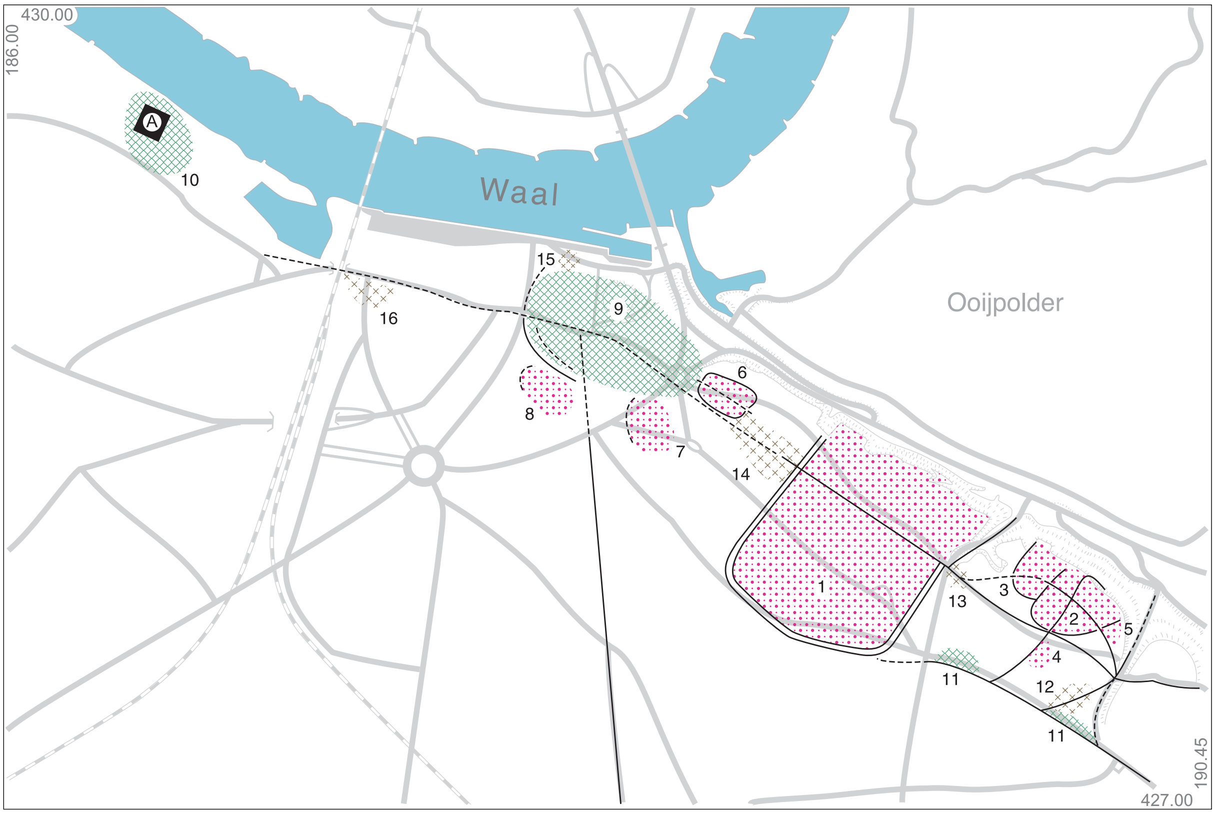

Fig. 2.7. Nijmegen in the Early Roman period (Willems/Van Enckevort 2009, fig. 4). 1: Augustan legionary camp on the Hunerberg; 2: Command post on the Kops Plateau; 3-8: Encampments for auxiliary troops; 9: Oppidum Batavorum; 10: Batavodorum (?).

command post. There seems to have been limited influence of the military and urban centres on the surrounding area in the Early Roman period: Early Roman imports are rare outside Nijmegen.[270]

48. Nijmegen-Trajanusplein (Nijmegen 1a)

The camp Nijmegen-Trajanusplein was located to the east of *Oppidum Batavorum* and is believed to have been in use for a short time in the second decade A.D.[271] The *castellum* was probably built to guard the crossing of the Waal and the civilian settlement *Oppidum Batavorum*, although it may also have been related to the army of Germanicus.[272] The animal bone assemblage contains 276 identified fragments, and was analysed by Lauwerier.[273]

49-50. Nijmegen-Augustan camp

Excavations on the Hunerberg (1987-1997), behind the Canisiuscollege, uncovered remains from the Augustan legionary camp as well as the western *canabae*, dating to the Flavian period (see site numbers 57-60). The Augustan camp provides insight into the earliest occupation of the research area.[274] Nijmegen was chosen as the base for a large military force in the conquest of the Rhine area. The

[270] Willems/Van Enckevort 2009, 21.

[271] Willems/Van Enckevort 2009, 21, 41.

[272] Haalebos *et al.* 1995, 11; Willems/Van Enckevort 2009, 41.

[273] Lauwerier 1988, 47-50. Lauwerier referred to this site as `Nijmegen 1a`.

[274] Haalebos *et al.* 1995; 1998; Willems/Van Enckevort 2009, 29-35.

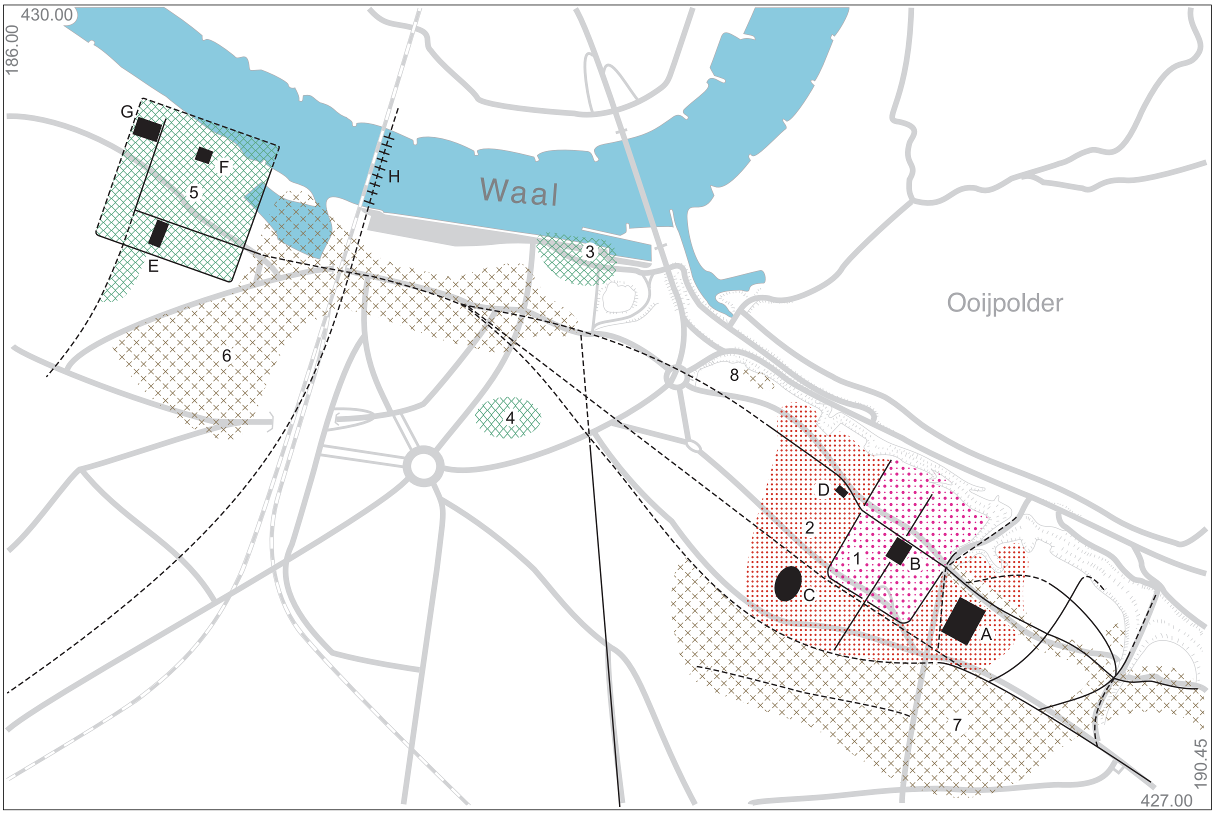

Fig. 2.8. Nijmegen in the Middle Roman period (Willems/Van Enckevort 2009, fig. 7). 1: Legionary camp on the Hunerberg; 2: Canabae; 5: Ulpia Noviomagus; E: temples for Fortuna and Mercury on the Maasplein.

Hunerberg formed a strategic location, with its high ridge looking out over the northeast. This was the most northerly camp on the Rhine. The Augustan camp was built in 19 B.C. and abandoned between 15 and 12 B.C. This was a large camp of 42 hectares that may have housed up to 15,000 men. The main structures that were excavated are the western gate (already discovered in 1918 by Holwerda, but then believed to belong to the Flavian *castra*) and postholes of several towers on the inside of a double ditch. Inside the camp, remains of several rows of barracks and officers' houses were found (fig. 2.9). In the Flavian period, the *castra* was built over the eastern half of the Augustan camp, while the *canabae* covered the western half. Botanical samples from five pits were analysed; the most remarkable find was olive (*Olea europaea*).[275] Animal remains from 39 Augustan pits were analysed by Koopmans.[276] She also describes Flavian material, but this was discovered to contain several Augustan features, and can therefore not be used; after all, the data cover both the Early and Middle Roman period, and come from different camps.[277] Thijssen also analysed some Augustan animal remains, from pits uncovered during earlier excavations (1975-1977).[278]

51. Nijmegen-Kops Plateau

After the Augustan legionary camp had been abandoned, the military presence moved to the Kops Plateau, to the east of the Hunerberg.[279] This command post was taken into use around 12 B.C. It offered a higher and better-protected location. Excavations were carried out from the 1970s to the 1990s.

275 De Hingh/Kooistra 1994.

276 Koopmans 1996.

277 Personal communication Rien Polak.

278 Thijssen 1988.

279 Van Enckevort/Zee 1996; Willems/Van Enckevort 2009, 20, 35-40.

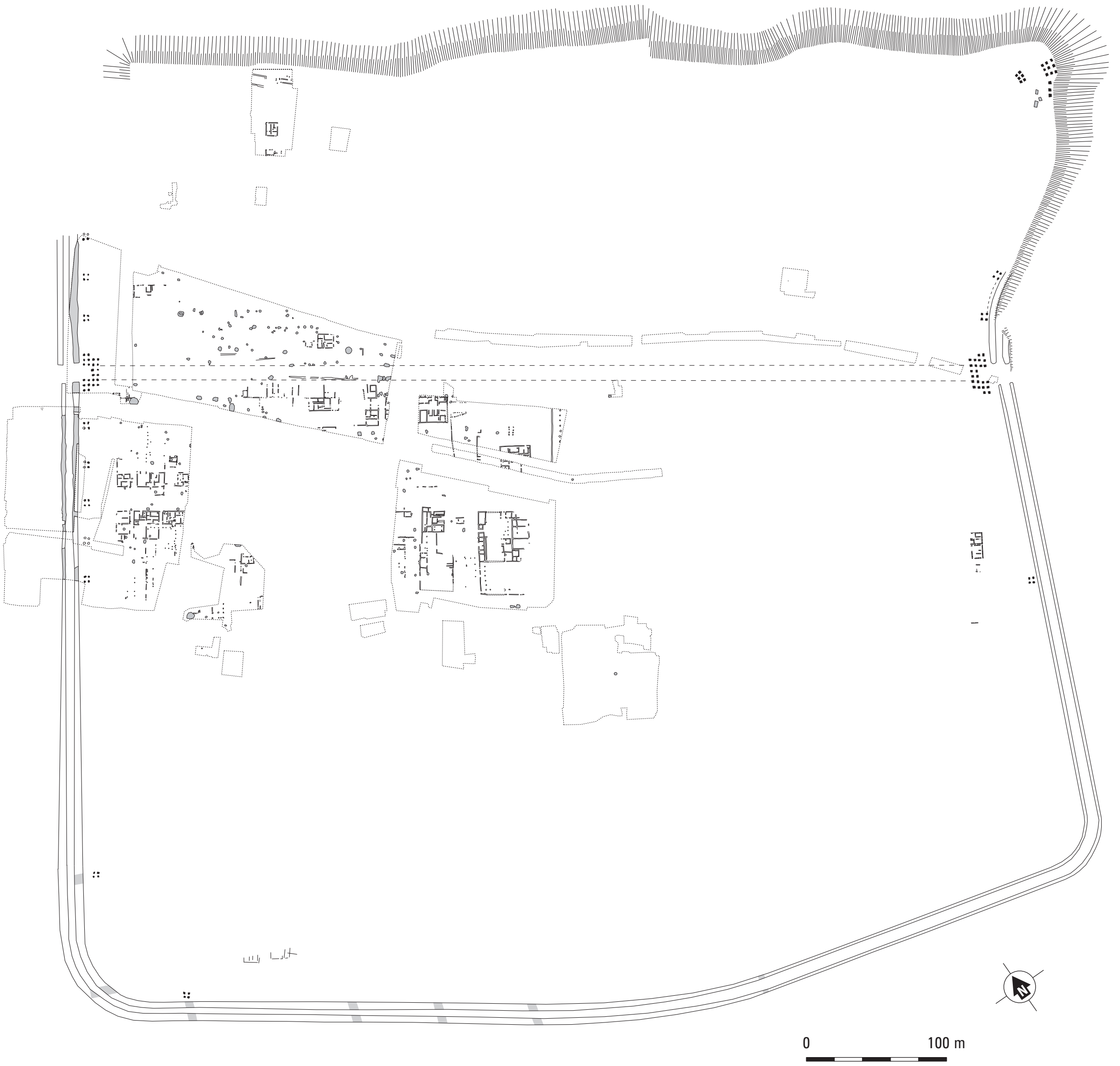

Fig. 2.9. Plan of the Augustan camp in Nijmegen (Willems/Van Enckevort 2009, fig. 9).

One of the most striking finds during the excavations was a large commander's palace. The size of the *praetorium* and the number of other buildings for officers suggest that this was the home of the commander of a large force with his staff and bodyguards, perhaps Drusus at first and later Tiberius, Varus or Germanicus. Other structures include a granary, smithy, bronze workshop and pottery workshop. The fort was surrounded by three phases of ditches. At different times, different units were stationed here, with legionary soldiers in the earlier phase and a cavalry unit in the later phase. Auxiliary troops were stationed outside the fort, and finds from this area include a stable complex, horse gear and horse graves. After the Batavian revolt in A.D. 69, a legion was stationed on the Hunerberg, and the Kops Plateau lost its military importance. The main animal bone assemblage was analysed by Whittaker.[280] Earlier analysis was limited to several special finds: a pot with preserved song thrushes, three mackerels in a jar and a concentration of fish remains.[281] Because of the size of the assemblage, Whittaker was

[280] Whittaker 2002.

[281] Lauwerier 1993.

able to analyse only 19 % of the faunal material, and identified 3857 fragments to species. He studied three different zones: 1. inside the fort; 2. the area around and in the defensive ditches; 3. outside the fort. Most of the material comes from the ditch area, especially near the southern gate.

52-53. Nijmegen-Castra

After the abandonment of the Augustan camp, the Hunerberg was unoccupied for a long time. After the Batavian revolt, a legionary fortress was built there, first in wood, and at the end of the 1st century in stone (fig. 2.10).[282] This stone-built fortress is the best-known monument in Roman Nijmegen. In this phase, the *castra* had a size of c. 16.5 hectares. *Legio X Gemina* was stationed here in A.D. 71, replacing *Legio II Adiutrix*. The legion remained here for about 30 years, until it was moved to the Danube in A.D. 104. In the 2nd century, detachments of several different legions were stationed in the fortress. Since 1916, archaeologists including Daniels, Holwerda, Brunsting, Bogaers and Bloemers have excavated in the *castra*; about half of it has been excavated. A large animal bone assemblage, collected during excavations in the 1950s, 1960s and 1970s, was analysed by Lauwerier.[283] The animal bones date to A.D. 70-120. Thijssen analysed a small assemblage of animal remains collected during excavations in the *castra* between 1975 and 1977.[284]

54. Meinerswijk

The *castellum* of Meinerswijk was first discovered during a soil survey. In 1979, a small excavation was carried out to establish the chronology of the site.[285] The features, such as stone wall foundations, and finds confirm the military nature of the site, and led to a chronology of six phases from the second decade of the 1st century A.D. to the Late Roman period. Since the excavated trench was small, little information about the construction and layout of the fort was gained. Willems believes that Meinerswijk is probably *Castra Herculis*, a fort known from Roman sources. The animal bones collected during the excavation date from c. A.D. 10-250.[286]

55. Wijk bij Duurstede-De Geer

The rural settlement in Wijk bij Duurstede-De Geer has already been discussed under site number 6. The same excavation uncovered structures and finds from the later Middle Roman period (A.D. 150-270). During the recent post-excavation analysis, Heeren argued for an interpretation of the Middle Roman features as belonging to a military post: a *statio* or supply base.[287] His arguments are based on the probable course of the *limes* road along the stream ridge on which De Geer was located, the lack of clear farmhouses, the size and shape of the enclosure, and the presence of possible granaries. The presence of offensive *militaria* (rather than the horse gear which dominates the *militaria* found in rural sites in this period) and pottery typical for military and urban sites strengthens his interpretation. Of the animal bone assemblage from this site, 292 fragments could be identified to species.[288]

56. Nijmegen-Valkhof

In the Late Roman period, a *castellum* was constructed on the Valkhof in Nijmegen, the plateau above the river Waal. The *castellum* was surrounded by two deep ditches, with a bank between them.[289] Outside the *castellum*, a Frankish settlement arose, while below the Valkhof, on the southern bank of the river Waal, a trading settlement was located. One of the large defensive ditches surrounding the

[282] Haalebos *et al.* 1995; Willems/Van Enckevort 2009, 24-25, 48-57.

[283] Lauwerier 1988, 52-64.

[284] Thijssen 1988.

[285] Willems 1984, 169, 194-195.

[286] Lauwerier 1988, 86-88.

[287] Heeren in prep.

[288] Bekkema *et al.* 2011.

[289] Willems/Van Enckevort 2009, 28, 100-102.

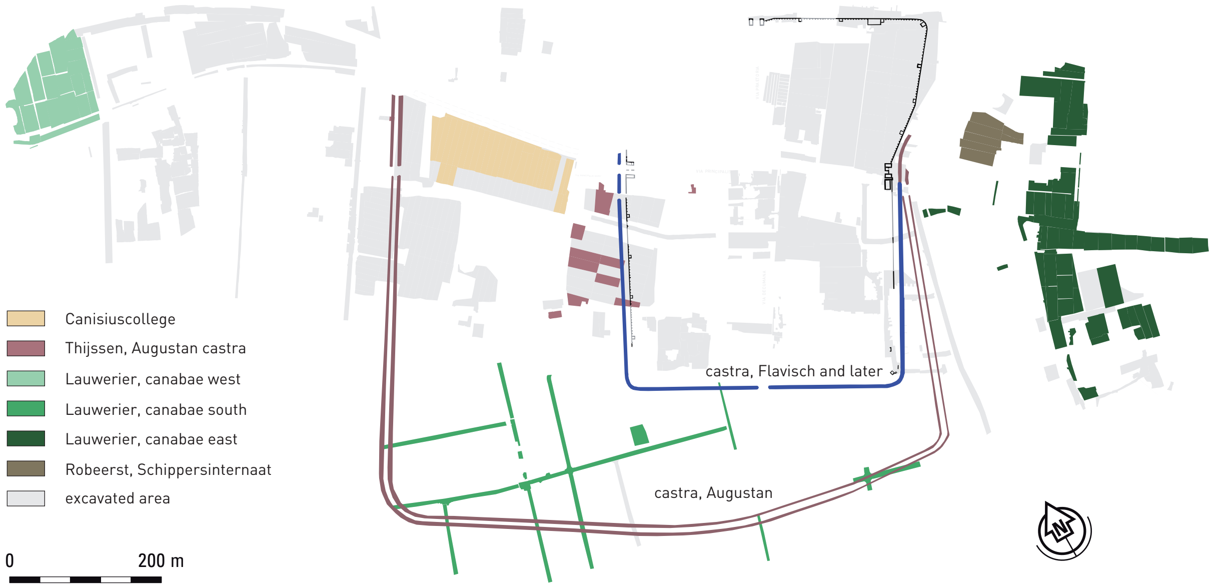

Fig. 2.10. The Hunerberg in Nijmegen, with the *castra* and *canabae* and the origin of the animal bone assemblages (Groot/Robeerst 2014, fig. 7.1; Illustration Rien Polak, Auxilia).

castellum was excavated in 1969 and 1979-1980. About 2000 animal bones collected from this ditch were analysed by Lauwerier.[290]

2.3.3 URBAN/MILITARY SITES

57-60. Nijmegen-Canabae

The presence of the legion on the Hunerberg from A.D. 70 attracted numerous people, such as craftsmen and traders. This led to the development of the *canabae legionis*, spreading along the road leading from the fortress (fig. 2.10).[291] The *canabae* extended around three sides of the fortress, covering more than 100 hectares (including the *castra*). Departure of the legion in A.D. 103 or 104 took away the economic basis of the *canabae*. The *canabae* was not abandoned completely, but greatly decreased in size in the first quarter of the 2nd century A.D. Later remains are rare. Excavations from 1972-1978 at the Schippersinternaat location uncovered a rubbish dump located outside the eastern gate of the *castra*. More excavations took place in the western *canabae* between 1987 and 1997, in advance of new building developments. The excavations took place on the terrain of the former Canisiuscollege and covered c. 3.5 hectares.[292] The excavations revealed striphouses, a peristyle house, hypocausts and a large building interpreted as a *mansio*, with a storage building next to it. Evidence for crafts and industries such as pottery making (at least three pottery ovens in different areas), metalworking, glass production, baking (two very large quernstones) and perhaps textile production was found. Graffiti provide some clues to the origin of the inhabitants of the *canabae* and include Latin, Celtic and Greek names. Graffiti of soldiers indicate that some were living or working in the *canabae*. During the earlier

[290] Lauwerier 1988, 64-76.

[291] Bogaers *et al.* 1988; 1989a; 1989b; 1992; Haalebos 1996; Haalebos *et al.* 1993; 1994; 1995; 1998; Willems/Van Enckevort 2009, 26, 59-64.

[292] See Kloosterman *et al.* 2014 for a recent publication on the structures and finds from the Canisiuscollege excavations.

excavations, part of a large building had been excavated, and more was uncovered during excavations between 1997 and 1999. This has been interpreted as a *forum*; the square inside was used as a seasonal livestock market.[293] Botanical remains from the 1987-1997 excavations were analysed, providing evidence for stored, imported cereals and imported and locally collected fruits.[294] An altar devoted by a trader in cereals from the area of the Nervii (near Bavay, northern France) is a further indication for the import of cereals.[295]

The first animal bone assemblage from the *canabae* (eastern, western and southern parts) dates to A.D. 70-120 and was analysed by Lauwerier.[296] The assemblage consists of a total of just over 3000 fragments, 1951 of which were identifiable. Some of the animal bones collected during the 1987-1997 excavations were analysed by Whittaker.[297] He was able to use a more detailed chronology than Lauwerier, with a distinction between the periods A.D. 70-100 and 100-130. The size of the second animal bone assemblage is similar to that of the first: c. 3000 fragments, with just over half identified to species. Robeerst also analysed animal bones collected during these excavations, but never published the results.[298] Her data were recently analysed and published.[299] The studied assemblage consists of 12,297 fragments of mammals, birds, fish and shellfish. This material could also be divided into two phases: an early (A.D. 70-90) and a late (A.D. 90-120) phase.[300] The fills of two Flavian pits, excavated in 1987 and 1989, were published separately.[301] Although of limited use because of a lack of quantifiable data, the sieved samples provide additional information on birds and fish. A small number of Late Flavian animal remains analysed by Koopmans (see site nr 49) is not contaminated.[302] Robeerst analysed a hand-collected animal bone assemblage of 2572 fragments from the Schippersinternaat site to test the hypothesis that this was refuse from the *castra*.[303] Her conclusion was that the rubbish dump contains refuse from the eastern *canabae* and not the *castra*.

61. Kesteren-Vicus

Excavations at this site took place in 1968, 1977 and 1984. During the 1977 excavations, rubbish pits and ditches were found, dating to the late 1st-2nd century A.D.[304] In the excavation in 1984, wall ditches of buildings were uncovered, with a starting date of A.D. 70. The type of building was interpreted as typical for a *vicus*. A *centuria* inscription indicates the (semi)military nature of the site. It is assumed that a *castellum* was located nearby, but its exact location is unknown.[305] The site was in use until the 3rd century. The main buildings are situated in a row, along an empty strip in the centre leading to an opening in the enclosure ditch, and thus suggesting a road. The size of the site was 4.5-5 hectares. Twelve botanical samples from a well, pits and ditches were analysed.[306] One sample contained waterlogged remains; the others only contained carbonised remains. Apart from the cereals emmer wheat, barley and millet, other crops present were beet, rape, flax, Celtic bean, opium poppy, coriander and dyer's rocket. The small assemblage of animal remains was analysed by Lauwerier.[307]

293 Driessen 2007, 130-135; Willems 1990, 51; Willems/Van Enckevort 2009, 61-64.

294 De Hing/Kooistra 1994; Kooistra 1989.

295 Haalebos *et al.* 1995, 69.

296 Lauwerier 1988, 52-64.

297 Whittaker 2002.

298 Robeerst's study was part of the research project *Roman Nijmegen: headquarters and capital in the region of the Batavians* (financed by NWO).

299 Groot/Robeerst 2014.

300 Personal communication Rien Polak.

301 Hoek 1988; Hoek/Brinkhuizen 1990.

302 Number of identified fragments=18. Apart from the normal mammals and chicken, plover (*Pluvialis sp.*), barbel (*Barbus barbus*) and wels catfish (*Silurus glanis*) are present.

303 Robeerst unpublished.

304 Hulst/Noordam 1977b; Hulst/Greving/Van Arler 1984.

305 Van Es 1981, 104.

306 De Hingh 1992.

307 Lauwerier 1988, 88-89.

62. Utrecht-LR46 Vicus

Part of the same excavation as Utrecht-LR46 Settlement (site number 33), this refers to the *vicus* adjacent to *castellum* De Meern. In 2004, part of the southern part of the *vicus* was excavated, as well as a small section in the northeast.[308] The northeastern area did not reveal much at all. In the southern area, pre-Flavian ditches pre-date the *vicus* and were part of a parceling system that may well have been laid out by the Roman army. A road serves as the southern boundary of the *vicus*, and ditches and pits adjacent to the road point to activities in its southern part. There are no traces of habitation in the 1st and 2nd centuries. Finds of manure fungus and grass seeds suggest that livestock was kept in this area. Several elongated pits were excavated, which may have been used to process flax. In the early 3rd century, a building was located here. The small size of the excavated area makes it difficult to say much about the activities in the *vicus*. A small animal bone assemblage from the *vicus* was analysed.[309]

63. Utrecht-LR58 Vicus

Utrecht-LR58 is part of the same *vicus* as LR46 (site nr 62), but located to the north, in the periphery of the *vicus*.[310] The chronology consists of five phases. Only a few features date to the first, (pre-?) Claudian phase; a block of three buildings and a granary date to the next two phases. For phase 4 (A.D. 70-110), three buildings with yards were excavated. The last phase dates from A.D. 150 and provides evidence for craft activities, probably metal production and working. Seven botanical samples were analysed, yielding evidence for imported cereals and Roman herbs.[311] The animal bones from Utrecht-LR58 were analysed, but unfortunately, the majority of the animal bones is unphased.[312] Since phase 4 is best represented among the phased material, it seems reasonable to assume that most of the unphased bones are from this period.

2.3.4 URBAN SITES

64/65. Nijmegen 1bc/Oppidum Batavorum

The first civilian settlement in Nijmegen was founded around 10 B.C. and was located on the Valkhof.[313] It is known as *Oppidum Batavorum*, and considered to be the administrative centre of the Batavians. No traces of public buildings have been found so far. The settlement shows an urban lay-out, with long plots at right angles to the main street. It mostly consists of wooden buildings, but some stone foundations and brick fragments have been found. The total area may have covered 20 hectares. The inhabitants were probably veterans and Gallo-Roman immigrants (traders) who followed the Roman army north. The animal bone assemblage dates to A.D. 25-70.[314] It is of a reasonable size: c. 1500 fragments, with 854 allocated to species. A second, larger, animal bone assemblage was analysed by Robeerst; this consists of over 2000 fragments, with 1318 fragments identified to species.[315]

66/67. Nijmegen-Maasplein and Nijmegen-Weurtseweg (Ulpia Noviomagus)

After the Batavian revolt in A.D. 69, a settlement developed on the western side of the modern town, on the bank of the river Waal.[316] Around A.D. 100, it was given market rights (*ius nundinarum*) by Trajan. Large areas were excavated here in the 1980s and 1990s. Most of the excavations have taken

308 Langeveld 2010a.

309 Groot 2010a.

310 Langeveld in prep.

311 Kooistra 2008.

312 Esser 2012.

313 Van Enckevort/Thijssen 1996, 55-56; Willems/Van Enckevort 2009, 21, 70-72.

314 Lauwerier 1988, 50-51.

315 Robeerst 2005a.

316 Van Enckevort/Thijssen 1996, 67-76; Willems/Van Enckevort 2009, 26, 73-79.

place in the southern periphery of the town. The town was built with a rectangular street plan, and included stone public buildings, such as baths and two Gallo-Roman temples. Parcels were long and narrow, with houses adjacent to the roads and gardens at the back. A thick cultural layer suggests that the soil was cultivated. This area of the town shows a development from craft and industrial activities – mainly pottery kilns – (A.D. 70-100) to the building of the large temple complex and upper class housing in the early 2nd century – after a fire had destroyed much of the area. The town burned down again near the end of the 2nd century, after which it never reached its former size and prosperity. The temple area fell out of use at this time. Most of the 3rd-century finds and features indicate craft and industrial activities. Large pits and ditches were completely filled with heavily fragmented animal bones, suggesting large-scale processing of meat. Around A.D. 260 the town was abandoned. A large animal bone assemblage from the site Maasplein was analysed by Filean, distinguishing three phases: I/II: A.D. 70-150; II: A.D. 150-200; III: A.D. 200-270.[317] A large animal bone assemblage (over 7,000 fragments; c. 2200 identifiable fragments) from the site Weurtseweg was analysed by Whittaker, also distinguishing three phases: 1: A.D. 65-160; 2: 2nd century A.D.; 3: 3rd century A.D.[318]

2.3.5 TEMPLES

68. Elst-Grote Kerk/69. Elst-St. Maartenstraat

In 1947, foundations of two Gallo-Roman temples were discovered during an archaeological investigation of a church that was damaged during the Second World War.[319] The oldest temple consists of a simple rectangular stone building, while the later one has a *porticus* and monumental stairs. This is one of the largest temples of its kind. In 2002-2003, archaeological investigations took place in the church cemetery and the car park.[320] The reason for this was the discovery of Roman remains during construction activities in the Sint Maartenstraat in 2001. The aim was to establish the boundaries of the temple site and to place the temples within their spatial context. Dated finds, dendrochronological dates of oak foundation posts and investigation of the building style of walls made it possible to achieve more reliable dates for the two temples. The first stone temple was dated to A.D. 50-100, although the start date could also have been a few decades later. The second stone temple was dated to A.D. 100-225.[321] Derks believes that the building of the monumental temple fits within the process of political integration of the Batavians in the Roman Empire.[322] Stone walls were found in several locations, but it remains uncertain whether these are part of the enclosure of the temple site.[323] A layer containing a large number of animal bones preceded the first temple phase, and was dated to c. 40 B.C. – A.D. 50. It was related to the beginning of the cult at this site. The find of a bronze club, which was part of a statuette, is a strong indicator that the temples were dedicated to Hercules Magusanus.[324] Lauwerier analysed animal bones collected during the older excavations – 803 identified fragments –, while animal bones from the more recent excavations were analysed by Robeerst – 1748 identified fragments.[325] Lauwerier could distinguish two phases (a pre-temple and temple period), while three phases were distinguished in Robeerst`s analysis: the pre-temple phase, temple 1 and temple 2.

[317] Filean 2006.

[318] Whittaker 2002.

[319] Bogaers 1955; Derks/Hoff 2008.

[320] Derks *et al.* 2008.

[321] Heeren *et al.* 2008, 31, 33-43.

[322] Derks 2008, 137.

[323] Heeren *et al.* 2008.

[324] Van Renswoude 2008b, 77.

[325] Lauwerier 1988, 111-121; Robeerst 2008.

70. Elst-Westeraam

In 2002, fragments of stone and tiles were found in an area where new housing was developed. These turned out to be the remains of a Gallo-Roman temple.[326] Excavations started the next day. Although the building and the foundations had mostly been destroyed, enough remained to reconstruct the development of the cult site. The first construction on the cult site is a small wooden building, dated to c. A.D. 10-20. This building was replaced by a second building, and the cult site was enclosed by a double wooden ditch and a palisade. Around A.D. 70, the building was replaced by a similar one, with a different orientation. The stone Gallo-Roman temple was constructed around A.D. 100, after the previous building had burned down. The temple was abandoned in the last quarter of the 2nd century. Fourteen small bread ovens were found within the temple enclosure. Since the temple is so close to that of Elst-Grote Kerk (650 m), it seems likely that it was devoted to another god.[327] Archaeobotanical research of carbonised seeds identified barley, emmer wheat and cultivated oat.[328] One grain is from either spelt or bread wheat. The only other evidence for food plants is a cherry stone (*Prunus avium/cerasus*). Burned food remains were analysed and identified as bread and porridge.[329] The animal bone assemblage from the site was divided into two phases: a Late Iron Age settlement to the west of the cult site, and the material related to the cult site.[330] Both sub-assemblages are small.

71. Empel-De Werf

The 0Gallo-Roman temple of Empel-De Werf was excavated in 1989-1991.[331] The site is located on a Pleistocene river dune, surrounded by clayey soils. The Gallo-Roman temple has a pre-Roman origin: coins, brooches and sword fragments show that the site was used in the later 2nd and 1st centuries B.C. No buildings or features are known for the Late Iron Age cult site. It is assumed that a small building was constructed around the middle of the 1st century A.D., but no evidence has been found for this. The Gallo-Roman temple was constructed in the Flavian period, and remained in use until c. A.D. 235. During the archaeobotanical research, one seed of a fig was found, as well as elderberry. Pollen of different types of cereals was seen as evidence for the presence of harvested cereals or cereal products.[332] A sizable animal bone assemblage was collected from the temple site.[333] The bones can be divided into two phases: before the temple was built (25 B.C. – A.D. 70), and the period that the temple was in use (c. A.D. 150-235). Most of the animal bones (85 %) from the pre-temple period were collected from a clay layer and one pit. More than 90 % of the animal bones from the temple period comes from three wells. The preservation of animal bones in sandy soils is rare, and it is due to the particular circumstances of the features that any bones were found at all. One sample from a well was sieved, and has yielded a number of bird bones.

72. Nijmegen-Fortuna temple

Several public buildings were erected in the town of *Ulpia Noviomagus*. A bathhouse and two temples on the Maasplein are the only ones known.[334] The 10th legion was involved in building the temples. The southern temple was dedicated to Fortuna, while Mercury was worshipped in the northern temple. The temple area was in use until the late 2nd century. Archaeobotanical and zooarchaeological analysis of remains found in the temples has been carried out.[335] Among the botanical macro-remains were figs, dates (*Phoenix dactylifera*) and pine nuts (*Pinus pinea*). The animal bones are mostly burned.

326 Van Enckevort/Thijssen 2005.
327 Derks 2005, 29.
328 Van Haaster 2005.
329 Kubiak-Martens 2005.
330 Robeerst 2005b.
331 Roymans/Derks 1994.
332 Groenman-van Waateringe/Pals 1994.
333 Seijnen 1994.
334 Van Enckevort/Thijssen 1996, 77-79; Willems/Van Enckevort 2009, 77.
335 Hänninen/Vermeeren 1997; Thijssen/Vermeeren 1996; Zeiler 1997.

3. Zooarchaeological background

This chapter will provide some background on the main zooarchaeological aspects that are investigated in this study: species proportions, age and sex, skeletal elements, butchery and measurements. This includes methodological considerations and previous research.

3.1 Species proportions

The proportions between the most commonly found animals indicate their relative importance in animal husbandry. In analysing changes in species proportions, there are several methodological problems. First of all, our data consist of remains of dead animals, whereas we are interested in the living herd as well as slaughtered animals. This is a more general methodological problem that also applies to age data. The exploitation of farm animals includes killing some of them, either for meat (slaughtering) or because they are not useful (culling). However, the exploitation of living animals for products such as milk, wool, labour (traction or riding) and manure is just as important. Animals exploited for such products may still be killed at the end of their useful life (i.e. when they no longer produce offspring, the quality of their wool decreases or they are no longer able to pull a plough). A second problem is inherent to using proportions. When the proportion of one species increases, it is not possible to establish whether this is because the actual number of individuals of this species increases, or whether their number remains stable, but numbers of the other species decrease. In this sense, we are dealing with relative changes, and references in the text should be understood in this way: when a species is said to increase, it increases *in proportion* to the other species. Of course, it could also be said that the other species all decrease in proportion. Finally, in material which has been collected by hand rather than by sieving – which is the case for most of the animal bones in this study –, the smaller mammals are likely to be underrepresented because of the smaller size of their bones.

3.2 Age and sex

In order to reconstruct animal husbandry practices, it is not enough to know the relative importance of the different domestic species. Slaughter patterns reveal insight into the exploitation focus: animals raised for meat will generally be killed at a younger age than those used for wool, milk or traction.

The assumption is that economic reasoning was the main factor influencing slaughter age. Cultural factors, such as a taste for either young or old animals, are not taken into account.

The optimum slaughter age for livestock kept for their meat is primarily based on the input-output ratio: how much food is put into an individual animal versus how much body weight (and thus meat) it will put on. Most animals grow quickly for the first part of their lives; in young adulthood, the growth ratio slows down. This is the basis for interpreting mortality profiles in zooarchaeology.[336] What is usually overlooked is the price or value of the fodder and any necessary labour that is put into the animal. Animals that are extensively grazed (as long as pasture is widely available) and require little attendance

[336] Payne 1973, 281-284.

from humans are thus easier to keep than animals that are stabled and require fodder on a daily basis. This means that there is less pressure to slaughter them. Complicating factors in the interpretation of mortality profiles are thus the pressure on pasture, the availability of fodder when extra feeding in winter is required, the stabling space that is available and the required and available amount of labour (for herding, shearing wool, gathering fodder, etc.).

Roman-period cattle were slower to mature than modern breeds of beef cattle,[337] and their 'basic' optimum slaughter age is therefore likely to have been higher than that of modern animals. However, this is not what is found in actual mortality profiles. Slaughter peaks are regularly observed for quite young age categories.[338] For people in the past, factors other than just input-output of food-meat played an important part in deciding when to slaughter their livestock. One more factor needs to be kept in mind. In a modern meat production system, animals are sent to slaughter as soon as they reach the required age or body mass. In the past, subsistent farmers would have taken the factors discussed above into account, but what also decided the moment of slaughter was the need for meat. There is no point in slaughtering several cattle at the optimum moment, when there is only one family to eat their meat. Of course, some meat may have been preserved, but this required salt, which had to come from the coast. Even when animals were sent for slaughter outside the settlement, the actual moment may have depended on the timing of markets or the visit of a merchant or a representative of the authorities collecting requisitioned animals.

Meat is not the only reason to keep livestock. Cattle can provide milk, manure and labour; the last two products are vital for arable farming. A dairy herd will be composed primarily of adult females. Since cows only lactate after calving, and not all calves are needed to replace old cows, a surplus of calves is typical for dairying. Male calves will be slaughtered at a young age, with the exact age dependent on whether the calf's presence is needed for the cow to be milked and the demand for beef cattle, for instance from a nearby market.[339] Vigne and Helmer looked for a post-lactation slaughtering peak at 5 to 9 months in combination with a peak in 4-to-8-year-old cows to identify dairying in Neolithic Europe and the Near East.[340] Where large numbers of newborn calves are found, this can indicate either natural mortality, deliberate slaughter for special reasons, or the existence of techniques that caused cows to release their milk without the calf present.[341] Sheep can provide milk and wool. When milk is regarded as their main product, the flock should mainly be composed of adult females, with a surplus of lambs.[342] Both male and female sheep have wool, but the quality of male sheep (especially castrated ones) is better than that of the ewes.[343] If wool is the main product of sheep, little slaughter of lambs or prime-meat animals will occur, and most sheep will reach relatively high ages.[344] Reasons to slaughter older wool sheep are a decline in the quality of the wool or barrenness in the case of ewes. Where Payne described three models for meat, milk and wool, Vigne and Helmer believe two more are needed to explain exploitation of sheep and goats.[345] They added a type B meat model, where sheep are killed for meat between 1 and 2 years rather than between 6 and 12 months, and a type B milk model, where no slaughter of very young lambs takes place; instead, a smaller proportion of animals is killed between 6 and 12 months. In the models for milk and wool, sex as well as age is important. Unfortunately, sex determinations for cattle and sheep in Roman assemblages in the Netherlands rarely reach large enough numbers that these can be taken into account in interpreting age data.

337 Lauwerier 1988, 135; Filean 2006, 363.

338 E.g. Groot 2009a, 366, 375; Groot 2008a, 47, 52, 57.

339 Legge 1981, 170, 172, 180; McCormick 1992, 202-203.

340 Vigne/Helmer 2007, 28-29.

341 Vigne/Helmer 2007, 29-32; See Lucas 1989 for examples of such techniques in Early Medieval Ireland.

342 Payne 1973, 281, 283 fig. 2.

343 Payne 1973.

344 Payne 1973, 281, 284 fig. 3.

345 Vigne/Helmer 2007, 23.

So far, we have discussed factors influencing the moment of slaughter of livestock. There are also problems related to the data and methodology used to reconstruct mortality profiles. Although the slaughter age is certainly of interest, what we would ideally want is a reconstruction of the *living* herd. The composition of the living herd would give the best insight into how the animals were exploited. Since zooarchaeological data are by definition based on *dead* animals, no attempt is made here to reconstruct a living herd. Therefore, conclusions about exploitation are based on slaughter ages.

A second methodological issue is the movement of live animals. In a production system, animals raised for meat are moved and killed elsewhere. Local slaughter and production of processed meat products is a possibility, but there is little evidence for this (as we shall see in paragraph 5.5). An important consequence of the transport of live animals is that no evidence for them is found in the production sites. Even worse, if a selection of certain age categories for meat animals transported to consumption sites occurred, then this could skew the age data. Therefore, a comparison with the assumed destination of the rural animals – urban and military sites – is important.

Finally, in the rural Dutch River Area, animal bone assemblages reflect a mixed consumption and production system, since most or all meat consumed by rural people would have been produced by themselves (or their neighbours). Moreover, there is a high probability that animals were not just exploited for one product. Farmers are likely to have provided for their own needs in the first place, providing a modest surplus in the second place. The chance of finding clear indications of specialised types of production in mortality profiles is thus small.

3.3 SKELETAL ELEMENTS

Skeletal element distribution is mainly determined by two factors: the taphonomical history of the bone assemblage, and human manipulation of carcasses and selection of certain body parts.[346] For the smaller species, such as sheep and pig, the presence of smaller elements such as phalanges will also be heavily influenced by whether sieving is carried out or not. With the aim of uncovering human behaviour, zooarchaeologists sometimes tend to attach too much importance to the human factor in skeletal element distribution. This is not to say that it is not possible to draw conclusions from skeletal element analysis, but we should be aware of the other factors influencing skeletal element distribution.

Schmid described how industrial or craft activities can be deduced from skeletal element distribution. An assemblage from medieval Basel shows clear evidence of tanning: 166 horncores of goats were found together with tannery waste on a river bank.[347] On this basis, a large quantity of horncores and footbones from sheep and goat found in Roman Augst was also interpreted as tannery waste.[348] Another concentration of horncores from Augst – 207 horncores from cattle found in a cellar in Insula 31 – was given a different interpretation. Since the horncores were intact and displayed cutting marks at the point of attachment – suggesting that the horn was removed –, this assemblage was seen as waste from hornworking.[349] Schibler and Furger later described several more animal bone assemblages from Augst with an overrepresentation of horncores and/or footbones, mostly from sheep and goats.[350] Serjeantson discusses the evidence for tanneries in more detail, and argues convincingly that concentrations of horncores and footbones should be seen as tannery waste.[351] Other forms of evidence are tanning pits, leather offcuts, plant remains such as oak bark and certain tools. Serjeantson also gives an explanation

346 Of course, this is also part of the taphonomical process, but I want to distinguish between deliberate human actions and non-deliberate or non-human taphonomical factors.

347 Schmid 1972, 45.

348 Schmid 1972, 45-46.

349 Schmid 1968; 1972, 47-48.

350 Schibler/Furger 1988. See also Deschler-Erb 2012a and 2012b.

351 Serjeantson 1989.

for why tanners would want the feet left on the hides. Oil was required in the tanning process for making the leather supple. Neatsfoot oil is made from the phalanges and sometimes the metapodials of cattle, and it seems that tanners acquired hides and a source of oil at the same time. The horn was taken off the hides by the tanner and passed on to hornmakers.[352] Concentrations of horncores can thus either be interpreted as waste of hornmakers or tanners, and depends on other factors. Holes in the horncores suggest that animals or hides had been hung from the horns, and since this would make the horns useless, such horncores should be associated with tanners rather than hornworkers.[353] In any case, there was probably a close relationship between tanners and hornworkers in the past, both because they used the same supply of raw material, and because they were often located close together.[354]

Other examples of industrial bone waste are that of gluemaking, marrow production and boneworking. Typical assemblages representing refuse of the first two activities consist of hacked-up fragments of long bones, with a clear selection of the larger bones (humerus, radius, ulna, femur, tibia). Examples from various Roman towns are known, including Augst, Cologne, Arras and York.[355] A heavily fragmented bone assemblage from the *castellum* of Zwammerdam was initially interpreted as refuse from a soup kitchen. However, this interpretation has now been refuted; marrow production seems a better explanation.[356] Boneworking waste from Augst consists of sawn-off epiphyses, longitudinally split diaphyses and half-products.[357] Evidence for boneworking in Roman Winchester consisted of a combination of very fragmented long bones of cattle and horse – nearly all of which show marks of chopping or working – and bone objects damaged in the final stages.[358] These examples all relate to industrial waste. This typically consists of large concentrations of bones with a dominance of certain skeletal elements and/or animal species. Such assemblages are typically found in Roman towns.

Several zooarchaeologists have suggested that cattle hides were produced and transported out of rural sites in the research area.[359] This is based on an underrepresentation of horncores and phalanges. For Zaltbommel-De Wildeman site A, an overrepresentation of cattle mandible fragments is suggested to be a side-effect of the production of brawn, a preserved meat product made from cattle brains and the meat attached to the skull. Two scenarios are presented: either cattle heads were brought to the settlement from elsewhere to be processed here, or they represent local cattle. In both cases, the question of what happened to the rest of the carcass remains unanswered.[360] At the site Utrecht-Wachttoren Gemeentewerf, animal bones from a 2nd/3rd-century deposit in a residual channel were interpreted as the waste from professional meat processing.[361] The assemblage seems to contain mainly refuse from the first two stages of butchery: skinning and dividing the carcass into large portions and taking the meat off the bone. Butchery marks on the horse and dog bones found in the deposit make the interpretation somewhat more complicated; horse hides with the head attached and consumption of horse and dog meat are tentatively placed within a ritual context.[362] Another assemblage from Utrecht-Leidsche

352 Serjeantson 1989, 139, 141.

353 MacGregor 1989, 119; Prummel 1978, 404-405.

354 MacGregor 1989, 119, 123; Serjeantson 1989, 141-142.

355 Berke 1989; Deschler-Erb 2006a; Lepetz 1996, 145-146; O'Connor 2000b, 54-55; Schmid 1968; 1972, 48-49.

356 Van Mensch 1979; Stokes 2000.

357 Schmid 1968; Deschler-Erb 1998; Deschler-Erb 2012a, 117.

358 Coy/Bradfield 2010, 307-309; Maltby 1989, 75.

359 Esser *et al.* 2010, 218; Laarman 1996a, 354; Zeiler 2001, 229, 232; 2007, 162-163, 166.

360 Esser *et al.* 2010, 217-219.

361 Esser 2013.

362 This would suggest a different ritual practice from that found in the Late Iron Age sanctuary of Gournay-sur-Aronde in Gaul, where horse was not consumed, although this was normal practice in the settlements. Méniel 1985; 2001. Since the butchery marks on horse and dog bones from Utrecht-Wachttoren Gemeentewerf are similar to those on cattle bones, and if this assemblage really contains the waste from a professional meat processing workshop, we should consider the fact that this butcher used meat from less desirable animals and passed it off as beef. Unscrupulous mislabeling of meat may be older than we think.

Rijn, Utrecht-LR60, is also described as deviating from normal settlement waste, due to an overrepresentation of the head and front legs of sheep. The removal of the hind legs (rich in meat) and skins with lower limbs attached is mentioned as an explanation for the skeletal element distribution.[363] The upper limb bones carry a lot of meat and lend themselves to preservation through, for example, smoking. There are some indications that certain body parts of pigs, such as hams, were sometimes transported. At the temple of Empel, for instance, bones from the hind leg were five times more common than those from the front leg.[364] If the production of processed meat for export, such as smoked hams, was important in the rural sites, we can expect to find an underrepresentation of the meat-bearing bones.

The interpretations mentioned above are based on three assumptions: first, that phalanges (and horncores) were left on the hide; second, that the data are representative for the skeletal element distribution of the entire site; and third, that the effect of taphonomy on skeletal element representation is negligible. The first assumption seems reasonable. Evidence for tannery workshops – with concentrations of horncores or footbones – is described, for instance, for Basel, Den Bosch, York and Tongeren.[365] Serjeantson provides convincing arguments for the association of horncores and footbones with tanners, partly based on other evidence such as tanning pits and leather offcuts.[366]

The second assumption is not as straightforward. Perhaps it is not as problematic for large excavations covering different parts of a site, but in smaller excavations, especially when these occurred either just in the periphery or just in the centre of a site, it could be a problem. It is likely that certain activities were habitually carried out in certain places within a site. Butchery, for instance, can be messy, and will be more likely to be carried out in the periphery of a settlement,[367] just as the dumping of quantities of refuse. Food preparation is more likely to occur in or near the house, and any remains from food preparation or consumption will end up closer to the house. This could have affected different animals in different ways. Meat from smaller animals such as sheep or pigs, for example, is prepared on the bone more often than beef. It is not just the location of the excavation that affects an animal bone assemblage; research strategy also has an effect. Whether any fills are sieved, and to what extent this is carried out, will partly determine the recovery of smaller elements such as phalanges. This effect is more pronounced for medium-sized than large mammals. Over- or underrepresentation of skull fragments of cattle can also be related to differences in how these are counted by different researchers. Cattle skulls are often extremely fragmented, and one skull can end up as hundreds of fragments. The actual count for the skeletal element distribution depends on how the researcher deals with this.[368] Are several skull fragments from the same feature counted as one or separately?

The third assumption is even more problematic. Earlier taphonomic research has shown that taphonomic processes have a major effect on skeletal element distribution. Brain's study of an assemblage of goat remains collected from a Hottentot village – where it was known that entire animals were butchered, and no elements were taken from the site – clearly showed large differences in the survival of different elements.[369] The mandible had the best survival rate, followed by the distal humerus and distal tibia. Survival for the metapodials was studied separately for the proximal and distal parts, and varied from c. 17.5 to 30 %. The survival rate of phalanges was low: less than 5 %, but we must

363 Meijer 2011, 109, 113, 118, 122.

364 Seijnen 1994, 165.

365 Schmid 1972, 45. Schmid also bases her conclusion on modern practice of tanners in Switzerland. Bond and O'Connor 1999, 371, 387, 420; Ervynck 2011; Prummel 1978; Vanderhoeven/Ervynck 2007.

366 Serjeantson 1989.

367 Although this does not apply to Roman towns such as Augst, where evidence for butchery – in the form of stone butchery counters – was found in the centre of the town. Deschler-Erb 2012c.

368 Using the total weight for each skeletal element would avoid this problem, but these data are seldom published and this was therefore not an option for this study.

369 Brain 1981, 23. The goat bones were discarded and collected on the surface, so there is a difference with archaeological material that is buried immediately or discarded in pits.

remember that these are goat phalanges, and that this assemblage suffered from extensive dog gnawing. Goat phalanges are small enough to have been swallowed whole by dogs, and this may have affected their survival. Also, retrieval by hand-collecting is likely to overlook smaller bones such as phalanges. While the hot desert conditions in the Hottentot village were different to those of the Roman sites in the Dutch River Area, the general trend of skeletal element survival should be similar.[370] Underestimating the effect of taphonomy is especially problematic in the case of an apparent overrepresentation of mandible fragments. As in Brain's study, the mandible is often one of the most common skeletal elements in archaeological assemblages. Perhaps the extent of the overrepresentation of mandibles is more an indicator for how much an assemblage has suffered from taphonomy than for human selection.

3.4 BUTCHERY

Butchery practices are determined by different factors, including anatomy, technology, culture and economy. Seetah attributed variation in butchery to location, the use of the meat, the age of the animal, the tool that is used, and the skill of the butcher.[371] The analysis of butchery practices in the Roman period offers potential because it can provide evidence of the spread of new techniques and tools. Butchery marks can also give insight into the presence of certain meat products, such as smoked shoulders of beef. Typical signs of smoked shoulders in Roman Augst are a perforation in the shoulder blade, in combination with parts of the articulation and spine having been hacked off.[372] Similar butchery marks are regularly found in Roman sites.[373]

For the Roman Netherlands, little research has been devoted to butchery practices. Lauwerier described butchery marks on all mammal species in his study, using his own recording system of butchery codes.[374] While this is precisely the detail that is needed for investigating butchery practices, it is unfortunate that he combined data from all his sites, since butchery practices at rural sites are likely to differ from those in towns and military sites. There are two publications dealing with a single animal or bone, in both cases indicating the consumption of horse meat.[375] Butchery marks are generally described as part of zooarchaeological reports, but the descriptions are very limited in most cases.

Detailed analysis of butchery practices has been carried out for Roman Britain, where butchery on urban sites was found to differ significantly from that on rural sites, with chop marks more common on urban sites and knife marks more common on rural sites.[376] Similar results were found in Northern France.[377] The butchery methods used in towns were aimed at speed.[378] On rural sites, in contrast, traditional butchery practices seem to have continued, although some new methods were introduced. Butchery on rural sites was not carried out by full-time specialists.[379] Although urban Roman butchery has been described as crude and unskilled, Seetah argues that it was highly specialised and efficient.[380] Seetah further concluded that on urban sites, cattle were butchered while hung; Peters, on the other hand, concluded that cattle were butchered while lying on the floor, on their right side.[381] This could

370 One effect of the desert climate was that horns survived for longer than bones, which is not the case in temperate climates. Brain 1981, 18.

371 Seetah 2006, 112.

372 Schmid 1972, 42-43. See Deschler-Erb (1992; 2013) and Schibler/Furger (1988, 70-71) for more examples from Augst.

373 E.g. in Nijmegen (Lauwerier 1988, 61), Bodegraven (Lauwerier *et al.* 2005), Woerden-Hoochwoert (Van Dijk 2008b), York (O`Connor 2000b, 54-55) and Lincoln (Dobney *et al.* 1996, 26-27).

374 Lauwerier 1988, 150-160.

375 Laarman 1996a; Zeiler 2005.

376 Maltby 1989; 2010.

377 Lepetz 1996, 139-142.

378 Maltby 1989, 91; Seetah 2006, 113.

379 Maltby 1989, 89.

380 Seetah 2006.

381 Peters 1998, 259; Seetah 2006, 113.

be an indication for regional differences in butchery. Seetah's experiments show that the Roman cleaver, unlike the modern one, was suitable for chopping through meat as well as bone; they further revealed that using a cleaver resulted in faster dismemberment of carcasses.[382]

For the Roman Netherlands, butchery marks on horse bones are interesting because it has been claimed that horse meat was not or rarely consumed in most sites south of the *limes*.[383] On the other hand, consumption of horse meat has been suggested for several rural sites, such as Houten-Doornkade, Tiel-Passewaaijse Hogeweg and Geldermalsen-Hondsgemet.[384]

3.5 BIOMETRICAL ANALYSIS

While bone measurements are taken as a standard during most zooarchaeological analysis in the Dutch River Area, so far relatively little has been done with these data. Traditionally, reconstructed withers height has been used as a means of identifying changes in size in livestock in the Roman Netherlands.[385] There are two disadvantages to this method. First, only one dimension of animal size is investigated: height. It is possible that the conformation of livestock changed in response to developments in agriculture (more need for plough animals) or market demand (meatier animals), but that this change was limited to a stockier build, without the withers height being affected. Second, to reconstruct withers height complete bones are needed. The number of complete bones depends on the size of the assemblage, fragmentation and preservation, and is generally small in any but the largest assemblages. Furthermore, it means that most measurement data remain unexplored.

3.5.1 POTENTIAL AND PROBLEMS OF BIOMETRICAL ANALYSIS

Biometrical analysis has various applications. First, biometrics can be used for species identification, or rather discrimination between wild and domestic species, such as pig and wild boar or domestic and wild cat.[386] Measurements can also be used to differentiate between sheep and goat.[387] Second, biometrics can be used to gain insight into the sex ratios of animals.[388] Finally, biometric studies can trace developments in size and shape of livestock, which is the main interest in this study. It has long been recognised that domestication goes hand in hand with a size decrease, and the moment of domestication for different species has been identified by analysing measurements over time.[389] Size increases and changes in morphology in livestock have been found in different periods and regions and linked with improvement or introduction of new stock.[390]

Although biometrical analysis can identify changes in size and shape of animals, identifying the cause behind such changes is less straightforward. Four possible causes should be taken into account when analysing biometrical data:

382 Seetah 2006, 114.

383 Lauwerier 1999; Lauwerier/Robeerst 2001.

384 Groot 2009a; Taayke 1984.

385 Groot 2008a; Lauwerier 1988; Robeerst 2005.

386 E.g. O'Connor 2007; Payne/Bull 1988.

387 Payne 1969.

388 Davis 2008, 999; Weinstock 2000.

389 Meadow 1999, 296.

390 E.g. Albarella (1997) for postmedieval cattle in Southern England; Albarella *et al.* (2008) for cattle, sheep, horse and chicken in Roman Britain; Davis (2008) for sheep in Portugal in the Moslem period; MacKinnon (2010) for cattle in Roman Italy; O'Connor (1995) for sheep in England in the late 18th-19th centuries; Thomas (2005) for later medieval and postmedieval improvements of cattle, sheep, pig and chicken in England.

1. Sex distribution. Many mammals, including cattle, are sexually dimorphic, with males larger and heavier in build than females. Proportionally, uncastrated bulls are larger than cows in all dimensions. Castration delays the time of epiphyseal fusion, and as a result, oxen are larger than cows and bulls. Their bones are longer and proportionally more slender.[391]
   When a shift in the exploitation of cattle occurs (with a related shift in sex distribution), this affects the distribution of measurements, with more or fewer larger animals. However, in actual practice, the effect of sexual dimorphism may not be a major problem. Bulls were probably always uncommon, since very few bulls are needed for breeding. Therefore, cattle populations consisted mainly of cows and steers, which are difficult to distinguish morphologically.[392]
2. Positive changes in nutrition, which can result in larger animals. For instance, when livestock is stabled over winter rather than left outside to forage for themselves, they may receive higher-quality food. Since Late Iron Age farmhouses already show evidence for the stabling of livestock, it is unlikely that stabling would have changed much in the research area.
3. Improvement of local stock. This may have consisted of a deliberate breeding strategy for larger animals, by selecting larger animals for breeding and culling smaller animals (thus preventing them breeding).
4. Import of larger cattle, introducing new genes to the local population.

Biometrical analysis can give some insight into the possible cause for size changes. Whereas the size of post-cranial bones is dependent on both genetics and environmental factors such as nutrition, tooth size is less sensitive to environmental factors. Therefore, when size changes are observed in post-cranial bones but not in teeth, a change in nutrition is a likelier explanation than the import of new animals. Changes in tooth size are a stronger indication for genetic changes.[393] Other archaeological data may give further clues as to which explanation is the most likely. For instance, the prevalence of non-metric traits, such as the absence of the lower second premolar in cattle, is believed to be genetic and may therefore vary between populations.[394]

3.5.2 Previous research in the Roman Dutch river area: cattle

Previous research carried out in the Netherlands has mainly focused on the withers height of cattle and horses. Lauwerier presented data on withers height for cattle from 11 assemblages from the Early to Late Roman period.[395] The data show a clear increase in size. Although sample size is a problem, especially for the earlier assemblages, the increase was found to be statistically significant. Cattle from the second half of the 2nd century A.D. and later are clearly larger than cattle from the 1st and early 2nd century. Lauwerier's conclusion was that cattle increased in size due to the Romanisation of stock-breeding practices. Tantalisingly, there also seems to be a size increase in the 1st century A.D., but this is based on only a handful of withers heights.[396] The data further show a homogenous population in the earlier assemblages, as well as in Late Roman Nijmegen.[397] On the other hand, the distribution for Druten-Klepperhei III, which is also one of the two larger assemblages, shows two peaks. Furthermore, there is a gap in the middle of the range, between 120 and 124 cm.[398] Of the two possible explanations (sexual dimorphism or two populations), Lauwerier favours the second explanation. His first reason is that length measurements show little sexual dimorphism, and the second is that both groups

[391] Fock 1966.
[392] Albarella 1997, 46.
[393] Thomas 2005, 74.
[394] Albarella 1997, 45; Thomas 2005, 74.
[395] Lauwerier 1988, 166-7, fig. 42, table 77.
[396] Lauwerier 1988, 166, fig. 42.
[397] Lauwerier 1988, 167.
[398] Lauwerier 1988, 168.

have more cows than bulls, when sex is determined using Howard's indices.[399] The smaller population of cattle in Druten-Klepperhei III is not significantly larger than that of the earlier assemblages from Nijmegen, but the second, larger population of cattle is seen as a group of imported animals.

Laarman's data from the rural settlement Houten-Tiellandt include eight withers heights ranging from 100 to 141 cm, with an average of 115 cm. He notes the presence of two large specimens, with withers heights of 127 and 141 cm. The data for Houten-Tiellandt are from a general 'Roman' period, and of limited use for studying developments over time.[400] Kooistra concludes that there were two groups of cattle in the Kromme Rijn Area: a smaller group (100-110 cm) and a larger group (125-130 cm). The larger animals are seen as plough animals, while the smaller ones were used for meat, hides and milk.[401]

Robeerst also analysed the increase in withers height of cattle, and could include more data from the Early Roman civilian settlement in Nijmegen (*Oppidum Batavorum*), as well as newer data from rural sites.[402] Her focus was on the Early Roman period, and she identified a size increase in Nijmegen as early as the first decades of the 1st century A.D. The similarity in size to the cattle from Tongeren led her to suggest that animals may have been imported from this region to Nijmegen.[403] Robeerst's claim that cattle in rural sites also increase by 10 cm in the early decades of the 1st century seems a little optimistic considering her sample size of three withers heights for rural sites.

In his study of cattle bones, Filean takes a critical look at the conclusions reached in earlier studies, which identified a two-peaked distribution in withers height of cattle.[404] He believes that there are problems with the interpretation of two separate populations, since it is not certain that the dates of the samples are exactly the same, or that the bones come from the same archaeological features. Filean also mentions several limitations to using withers height for identifying different populations of animals, such as the lack of control over the age and sex distribution of the sample and the limited use of only using length measurements. He also raises doubt about the reliability of the sex determinations made by Lauwerier, which formed an important argument for assuming two populations rather than sexual dimorphism. Using Albarella's approach of using ratios of distal width and smallest width of the diaphysis to greatest length,[405] Filean examined 24 metapodials from several sites. All variation observed could be accounted for by sexual dimorphism, or rather polymorphism since oxen are also present. Filean's results also show that long bones of oxen are not necessarily longer and slenderer compared to bulls, but that they can be more robust, depending on the age of castration. Late castration seems to have been practised in the Dutch River Area.[406] The increase of castrated cattle with larger withers heights created the illusion of a larger breed of animals. Filean does not deny that a size increase occurred in the Roman period, and relates this to an increased emphasis on meat production.

My own research showed size increases (as shown by withers height) in cattle in two rural settlements: Tiel-Passewaaijse Hogeweg and Tiel-Oude Tielseweg.[407] The data from these two adjacent sites were combined to reach a larger data set. Phases were also combined, and a comparison was made between the periods 50 B.C. – A.D. 140, A.D. 140-270 and A.D. 270-350. The largest increase occurs between the first two periods, from an average of 112 to 120 cm. An increase in size was also observed in the rural site of Geldermalsen-Hondsgemet.[408] The largest increase in mean withers weight, from 108 to 117 cm, took place in the early part of the Middle Roman period. A second increase to 123 cm occurred during the 2nd century, with another, smaller increase to 125 cm in the Late Roman period.

399 Howard 1963.

400 Laarman 1996a, 346.

401 Kooistra 1996, 123.

402 Robeerst 2005a.

403 Robeerst 2005a, 84-86.

404 Filean 2006, 409-421; 2008. The earlier studies are Lauwerier 1988 and Laarman 1996a and 1996b.

405 Albarella 1997.

406 Filean 2006, 419; although castration before metapodial fusion is suggested in Filean 2008, 112-113.

407 Groot 2008a, 91-93.

408 Groot 2009a, 368.

To sum up, previous studies of withers height have already identified a size increase in cattle during the Roman period. There seems to be some evidence for two separate moments when size increased (for possibly different reasons): one in the first decades of the 1st century A.D, and one in the 2nd century A.D. However, there is still a lot of uncertainty with regard to the change in size in cattle. For instance, the exact dates are vague, it is not clear where the changes occurred first and how they spread, whether a size increase is seen in all sites in the Dutch River Area, whether the size increase only relates to withers height and thus bone length, or also to the other dimensions, and how homogenous the cattle population of the Dutch River Area was. Moreover, the cause behind the size increase is still unclear: was it caused by a shift in sex ratios, by selective breeding and improved nutrition or by import of larger cattle and interbreeding with the local type?

3.5.3 Previous research in the Roman Dutch River Area: horses

In 1988, Lauwerier wrote that "there is certainly no general increase in withers height in the region during the Roman period".[409] He observed that horses in the Eastern Dutch River Area seem to be larger than those in other sites in the Netherlands, such as Rijswijk and Valkenburg, and that the larger size of horses in the *castra* and *canabae* in Nijmegen and Druten-Klepperhei could mean that the army used larger horses. A 2001 publication further investigated this hypothesis. An inventory was made of the withers height of horses in four different types of site: military settlements, *villae*, native settlements north of the *limes* and native settlements south of the *limes*. Again, it is claimed that no gradual increase in withers height of horses occurred during the Roman period.[410] However, the mean withers height differs for the different types of site. The withers height of horses found in the native settlements north of the Rhine is smallest with a mean of 132 cm, very similar to Iron Age horses. Horses from native settlements south of the Rhine are somewhat larger, with a mean of 137 cm. The largest horses, with a mean withers height of 144 cm, are found in *villae*, while horses from military sites are slightly smaller with a mean of 142 cm.[411] Some large horses are present in rural sites, and these are seen as breeding stock. The difference between 'military' and 'rural' horses is explained by the selection by the army of the largest locally bred horses.

Robeerst also examined withers heights for horses for the Early Roman period.[412] One conclusion was that Late Iron Age horses in the Dutch River Area were larger compared to those from other regions (*Gallia Belgica* and the *Germania* Rhine/Danube area). Horses from the Early Roman *Oppidum Batavorum* are only slightly larger than those from the Late Iron Age, but the sample consists of only seven specimens. In contrast, the other two regions show a significant size increase in the Early Roman period, presumably due to import of larger breeding stock and improvement of local horses. Robeerst concludes that the import of larger horses as breeding stock to improve the local type did not occur until later in the Roman period. An 'improvement programme' may have taken place, but this was limited to the negative selection of smaller animals. However, this does not explain why these smaller animals are also absent from the rural sites.

I also noticed an increase in the size of horses over time in two rural sites in Tiel-Passewaaij.[413] From the period 50 B.C. – A.D. 140 to that of A.D. 140-270, the average withers height for horses increased from 134 cm to 141 cm. The Late Roman period shows another, smaller increase to 143 cm. While data from the rural site Geldermalsen-Hondsgemet suggest a size increase in the Early Roman period, the sample size for the Late Iron Age and Early Roman period is small.[414] A second increase

[409] Lauwerier 1988, 173.

[410] Lauwerier/Robeerst 2001, 277.

[411] Lauwerier/Robeerst 2001, 277-279.

[412] Robeerst 2005a.

[413] Groot 2008a, 91-92.

[414] Groot 2009a, 369.

in the 2nd century A.D., from 133 to 142 cm, is based on a larger sample. As for cattle, the reason behind this size increase is unclear: selective breeding for larger horses, better food or crossbreeding with larger, imported animals?

While this study discusses horses, it should be understood that this includes mules. Distinction between the two is not easy, and none of the zooarchaeological reports included have positive identification of mules. However, Johnstone's study of equids in the Roman Empire concluded that as much as 40 % of the equids in the Rhineland were mules.[415]

3.5.4 Previous research in the Roman Dutch river area: sheep/goat and pig

Lauwerier included sheep/goat and pig when investigating withers height, but could not establish any developments due to the scarcity of data. So far, no other research has focused on size changes of these two species. Obvious reasons for this are the lack of data, since both species were generally much less common than cattle. Furthermore, pigs were generally slaughtered young, leaving few fused bones.

415 Johnstone 2004.

4. Methods

This chapter describes the main methods used in collecting and analysing zooarchaeological data for this study. Nearly all these data were taken from existing publications or unpublished reports; only one assemblage was analysed specifically for this study.[416] The variety of the publications and authors means that there are differences in the methods that were used and in the detail in which assemblages have been analysed and described. In many cases, the lack of primary data limited the use of the data set. The size of data sets further affects their usefulness, with larger data sets naturally having more to offer than smaller ones. Nevertheless, smaller assemblages were included in order to fully utilise the potential of the zooarchaeological archive for the Roman Dutch River Area.

4.1 Taphonomy

Taphonomy has a huge impact on zooarchaeological data. To investigate the extent of this impact, and whether it has affected the sites in the study area in similar ways, a taphonomical study was carried out. This study was limited to cattle, for three reasons. First, in theory, each species could have a different taphonomical history, depending on whether it was consumed, how the carcass was butchered and how refuse or diseased animals were dealt with. Second, cattle is the most common animal in most assemblages, and therefore provides the best data. For less common species, or those that fluctuate strongly over time, the number of fragments may be too small. Finally, since this study was carried out in the first place to help understand skeletal element distribution, which focuses on cattle, it seemed logical to limit the taphonomical analysis to cattle as well.

For 40 assemblages from 24 rural sites and five assemblages from military or urban/military sites, data on two major taphonomic agents were collected.[417] By looking at these two taphonomic agents (butchery and dog gnawing), we can get an indication of the impact of taphonomy. Butchery by humans will cause fragmentation of bones into smaller pieces. It is well-known that gnawing by dogs has a major effect on skeletal element distribution, since dogs favour porous ends of long bones, such as proximal humerus and distal femur. The percentage of loose teeth is the third variable which was recorded, and is taken as an indication of the degree of fragmentation and preservation of the animal bones.[418] In sites with bad preservation, such as those with sandy soils, bone can be lost completely, and a mandibular tooth row will be found as six loose teeth, resulting in a high percentage of loose teeth.[419] In sites with good preservation but high fragmentation, a mandible can be broken, resulting in six loose teeth and a number of mandibular bone fragments. High fragmentation means that an assemblage has suffered more from taphonomical processes such as butchery, trampling, weathering

416 Wijk bij Duurstede-De Geer.

417 Some more assemblages provided data on one of these two factors, but a taphonomic index could only be calculated when both factors are included.

418 De Jong (2005) uses a tooth-bone index instead of a percentage, but the outcome is the same. In this study, the percentage is based on the total number of fragments for cattle, instead of for all mammals including unidentified bones. Therefore, the percentage will be higher.

419 Incisors are not considered here, since they are easily lost even from complete mandibles.

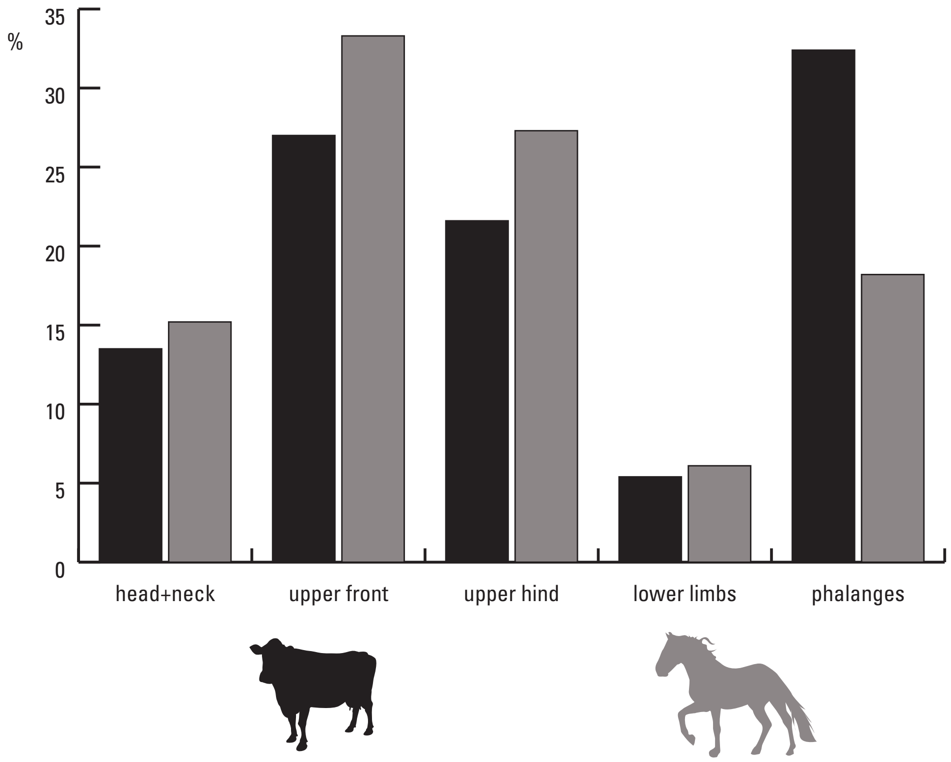

Fig. 4.1. Skeletal element distribution for a complete cattle and horse skeleton.

and gnawing. As a result, more fragile elements may have been lost, and stronger elements are more likely to be overrepresented. This can have an effect on mortality profiles, since younger animals with more fragile bones can be underrepresented. In sites with good preservation and low fragmentation, a mandible will be complete, resulting in a low percentage of loose teeth.

To assess the overall effect of taphonomy and fragmentation, a taphonomical index was calculated. Of course, this crude approach overlooks other taphonomical factors such as burning, trampling and weathering, but it provides a method that can be applied to many of the assemblages.[420] Even with this approach, a taphonomical index could not be calculated for all assemblages, since some included no exact figures on butchery and gnawing. The taphonomical index was based on the percentage of loose teeth (scores: 1: < 10 %; 2: 10-20 %; 3: 20-30 %; 4: > 30 %), the percentage of butchery marks (scores: 1: < 10 %; 2: 10-20 %; 3: 20-30 %; 4: > 30 %) and the percentage of gnawing (scores: 1: < 10 %; 2: 10-20 %; 3: 20-30 %). The taphonomical index is a figure between 3 and 11, with 3 representing assemblages with a minimal effect from taphonomical processes, and 11 representing assemblages that suffered extensively from taphonomical processes.

Apart from assessing the effects of taphonomical processes on animal bone assemblages, it is also important to establish whether the assemblage is representative for the site as a whole. A representative assemblage consists of a large number of bones collected from a variety of features throughout the site. Less representative assemblages come from either a limited area of a site or just one feature type, or consist of a small number of fragments. Sieving adds to the representativeness of an assemblage, since only when feature fills have been sieved can we assume to have evidence for the presence or absence of birds and fish. Sieving also has an influence on skeletal element distribution, with smaller elements

[420] Burning is usually not a major taphonomical factor in rural settlements in the research area, in contrast to cemeteries.

such as phalanges more likely to be underrepresented when sieving has not taken place, especially for smaller animals.

A second index was calculated to assess how representative a sample was. This index was based on scores for three factors: the size of the assemblage (cattle bones only, scores: 4: < 100 fragments; 3: 100-500 fragments; 2: 500-1000 fragments; 1: > 1000 fragments), the extent of sieving (scores: 4: no sieving carried out, or no sieve samples analysed, -; 3: limited sieving, +; 2: sieving more common and/or sieve samples analysed systematically, ++; 1: extensive sieving, +++), and the representativeness of the excavated area in relation to the entire site (scores: 3: not representative, only periphery or centre of site excavated or very small area, +; 2: not entirely representative because of the limited extent of the excavation or due to a dominance of one feature type, ++; 1: representative for the site due to the type, number and distribution of features from which bones were collected, +++). This index also ranges from 3 to 11, with higher numbers indicating that an assemblage should not be taken as representative. Although the index is limited to cattle, the extent of sieving and nature of the excavation apply to all species.

These two indices provide a rough idea of the likelihood of the assemblage reflecting the actual processes of production and consumption of animals, with lower figures representing the best assemblages. Besides the two indices, the average bone weight per fragment is used as an indicator for the impact of taphonomy and the quality of the excavation. If fragmentation is high, average bone weight will be low. However, the size of the fragments that are collected by hand can differ between excavations and further determines average bone weight.

4.2 SPECIES PROPORTIONS

The proportions of the main domestic animals provide a quick insight into their relative importance. This study is limited to four species: cattle, sheep or goat, horse and pig. When distinguishing between sheep and goats, identifications as published were followed. Not all publications include details about how the distinction was made; some authors used Boessneck's criteria.[421] In my own research in Tiel-Passewaaij, Tiel-Oude Tielseweg and Medel 6, identifications of sheep and goats were based on comparison with a reference collection and by using the criteria published by Boessneck.[422] Dog remains are present in nearly every site. While they may have played an invaluable role in animal husbandry, guarding or herding livestock, their meat was not consumed in this period, and there is no evidence that dogs were traded or sold. Wild mammals, birds, fish and molluscs are incorporated in a limited way: only presence/absence, percentage and species are considered. Wild mammals are present in most sites, but in very small numbers. Their economic contribution was small, although they may have been important in other ways, for instance in rituals or as symbols. Identifications of domestic pig and wild boar, and of cattle and aurochs, were also recorded as published in the site reports. Differentiating between domestic pig and wild boar is not always straightforward. In my own research, wild boar was identified by size alone. Roman domestic pigs in the research area are generally modest in size, and some of the bones were clearly much larger than domestic pig bones. Nevertheless, it is possible that some young or female wild boar have been misidentified as domestic pigs. Similarly, some young or female aurochs may have been misidentified as domestic cattle. The only cases where I have felt confident in identifying bones as aurochs is for the assemblage from Wijk bij Duurstede-De Geer, where two bones were very much larger than even the largest domestic cattle bones I had seen in the region.

421 E.g. Lauwerier 1988; Meijer 2011.

422 Boessneck 1969.

Similarly, the contribution of (wild) birds and fish is believed to have been insignificant economically.[423] Domestic fowl is present in many sites, and may have formed a more important contribution to the diet, both in the form of meat and by providing eggs. However, there are reasons for not focusing too strongly on chicken in this study. First, numbers are very small for most sites, which means that it would be difficult to do more than note presence or absence. Since not all animal bone assemblages include sieved samples, the presence and number of chicken fragments is difficult to interpret. Finally, chicken bones are smaller and more fragile than bones of domestic mammals, and taphonomy may act more severely on these fragments. Nevertheless, chicken will be discussed, because it is a new introduction in the Roman period in the research area. Apart from domestic fowl, domestic geese and ducks were also kept in the Roman period;[424] the problem is that distinguishing between wild and domestic geese and ducks is difficult. Since geese and ducks also occur naturally in the region, both in a variety of species and in large numbers, their overrepresentation among bird remains in archaeological sites is no indication for a domestic status.

In this study, an uncorrected count of bone fragments is used. For most assemblages, associated fragments were counted as one, but no attempt was made to correct for the different number of skeletal elements in the different species. Of all the factors influencing animal bone assemblages, this seems to be a minor one. In theory, this means that pig (with the highest number of skeletal elements) could be overrepresented, while horse (with the lowest number of skeletal elements) could be underrepresented. As we shall see, using a corrected figure would only have exaggerated the species proportions (with even fewer pigs, and even more horses). While the Minimum Number of Individuals can be useful since it is less biased by recovery, very few reports provide these data. Also, this figure is not very informative in small assemblages, and rarer species are always overrepresented in the Minimum Numbers of Individuals. There are also problems with using the total weight per species: for example, it varies according to the type of soil, and it results in an overrepresentation of larger animals.

Many regional or wider synthetic studies use triangular graphs to reflect proportions of animals.[425] This is based on the theory that there were only three main meat species: cattle, sheep/goat and pig. There are two reasons for including horse in the analysis of species proportions and using mainly bar charts. First, I am not only concerned with the dietary contribution of the four main domesticates, but also with their economic importance. As we shall see, horse plays an important part in the agrarian economy of the Roman Dutch River Area. Second, although horse meat was not consumed at all sites, there is enough evidence to conclude that it did form an occasional contribution to the diet, at least at many rural sites.[426] Nevertheless, in chapter 7 triangular graphs will be used to trace developments in meat consumption and supply from the Late Iron Age to the Late Roman period, since horse meat did not play a role in consumer sites.

Throughout this study, combined data per period or type of site and data per period for individual sites will be presented. In this way, it is possible to identify both general trends over time and differences between individual sites. The danger inherent to a synthetic study – losing sight of detail – is avoided in this way.

[423] Although the small numbers of bird and fish bones can be related to a lack of sieving, some sites where extensive sieving was carried out still yielded few bird and fish remains.

[424] See Peters 1998, 195, 213-215, 232-234.

[425] E.g. King 1984; King 1999; McKinnon 2004, 71; Valenzuela *et al.* 2013. King is explicitly concerned with diet.

[426] See paragraph 5.6.2.

4.3 MORTALITY PROFILES

The aim in this study is to identify the exploitation strategy for the four main domestic species and identify differences between sites and changes over time. Two approaches will be taken. The first uses pooled data from all sites from the same period. This approach hides differences between sites, but increases the sample size, and will show broad trends over time. The second approach will compare data for sites with similar dates in order to show differences and similarities. For cattle, the aim is to identify whether they were kept for meat, dairy or traction. For sheep, meat, milk or wool are the obvious products. The age at which horses were slaughtered provides insight into whether they were regarded as a meat animal or not. Although we expect pigs to have been slaughtered young – producing meat is the only reason for keeping pigs – the exact age at which they were slaughtered can differ.

Mortality is analysed by using two methods of age determination: the fusion of the epiphyses of long bones and the eruption and wear of mandibular teeth. One of the problems related to these methods is that they sometimes yield different results. There are several explanations for this discrepancy. First, it can be a result of the methodology used. Translating biological events such as the fusing of long bones to absolute ages is an interpretation and not completely reliable. All estimates of fusion ages are based on modern animals, which are faster-maturing than ancient animals.[427] Also, the moment of fusion is dependent on many different factors, such as genetic background, nutrition and health. Furthermore, castration can delay fusion.[428] Another explanation is that bones of very young animals are more fragile than those of older animals, and are more likely to be lost to taphonomy. Therefore, early-fusing epiphyses will usually be underrepresented, and with them, the younger age classes. The normal expectation for a mortality profile based on fusion data would thus be a bias towards older animals. If non-adults are better represented in epiphyseal fusion data than in mandibular age data, another explanation must be sought. When the two types of data do not match, the tooth eruption and wear data are taken as more reliable, mainly because the preservation of teeth is less dependent on the age of the animal. A mortality profile based on tooth eruption and wear is less likely to be influenced by taphonomy and post-depositional processes than one based on epiphyseal fusion.[429] Furthermore, tooth eruption also seems less easily influenced by health and nutrition.

For most of the assemblages used in the analysis, mandibular eruption and wear for cattle, sheep and pigs was scored according to Grant.[430] Eruption and wear stages for the three molars lead to a mandible wear stage. Grant's system uses no absolute data, and therefore Hambleton's tables were used to assign Grant's mandible wear stages to absolute age categories.[431] Only assemblages with a minimum number of aged mandibles of 10 are included in the analysis. However, smaller numbers of mandibles have been included in composite mortality profiles for the different periods. For mandibles of sheep and goat, the primary data were corrected as advised by Vigne and Helmer,[432] and percentages calculated on the basis of the corrected data. Because some age categories are much shorter than others (e.g. 6 months compared to 2 years), this gives a better idea of the proportion of animals killed within an age range. Since the age categories used for cattle and pig include categories without absolute ages, these data were not corrected.

427 Lauwerier 1988, 135; Filean 2006, 363.

428 Moran/O'Connor 1994; O'Connor 2000a, 95.

429 Amorosi 1989, 11.

430 Grant 1982.

431 Hambleton 1999. Age categories follow those of Bull/Payne (1982), Halstead (1985), Higham (1967) and Payne (1973).

432 Vigne/Helmer 2007, 20-21. Every age category was calculated to represent one year, so a category lasting six months was multiplied by 2, while a category lasting two years was divided by 2.

For some assemblages, a different system was used to age cattle mandibles.[433] In these cases, age categories have been converted into Halstead's age categories (table E4.1). In his analysis of the assemblages from Oosterhout-Van Boetzelaerstraat, Nijmegen-Canabae, Nijmegen-Kops Plateau and Nijmegen-Weurtseweg, Whittaker also uses different age categories.[434] These have been converted into Halstead's categories for the purpose of this study (table E4.2).

The method used to age cattle teeth from Nijmegen-Maasplein (quadratic crown height) was also not compatible with the age categories used in this study.[435] In order to use these data, they were put into three broad categories: younger than two years, two to four years, and older than four years.

Tooth eruption and wear for horses was analysed by using two separate methods: the ratio between horses with deciduous teeth and horses with permanent dentition, and the adult age based on the crown height.[436] The first method tells us what percentage of horses was killed before reaching adulthood, while the second only applies to adult animals, and gives more insight into the age reached by horses once they reach adulthood.

For epiphyseal fusion, two methods of analysis were used. The first is a rough method, which compares the total number of fused and unfused epiphyses. This seemed the best way to incorporate data from smaller assemblages. A minimum number of 30 epiphyses was used. The percentage of unfused epiphyses indicates the maximum proportion of animals killed before adulthood.[437] This broad division between adult and non-adult animals should give some insight into whether animals were exploited for meat (before adulthood) or secondary products such as wool, milk, labour and manure. The adult category also includes the breeding stock, and a proportion of both categories will be natural mortalities (perhaps more in the non-adult category, as young animals are particularly vulnerable). The second method analyses the proportion of animals killed in certain age categories. This method was originally devised by Chaplin and incorporates classifying the different epiphyses into different age categories; the data on unfused and fused epiphyses are then all combined into one table.[438] The proportions of animals killed in each category are calculated by establishing the percentage of unfused epiphyses for that category, and then subtracting the percentage of animals killed in the previous category or categories. Since the available data for each assemblage are divided into three (pig and horse) or four (cattle and sheep or goat) age categories, a larger data set is needed.[439] Only data sets with a minimum of 75 epiphyses were included. The advantage of this approach is of course that it offers more detailed information about when non-adult animals were killed.

There are some problems associated with this method. The first is that it relies on the assumption that each epiphysis represents a separate individual. It is therefore necessary to leave out complete skeletons or associated elements; these should be considered separately. Second, taphonomy affects different bones or parts of bones differently depending on their bone density. This means that proximal humeri and tibiae, for example, will normally be underrepresented in comparison to distal humeri and tibiae. Since they fuse at different ages, this can distort the data. Next, some epiphyses occur more frequently in the skeleton than others: a cow, for example, has eight proximal first phalanges but only two proximal humeri. Some people adjust the number of scored epiphyses accordingly;[440] in this study,

433 Buitenhuis 2002; Halici 2004a.

434 Whittaker 2002, table 3.

435 Filean 2006.

436 The first method distinguishes between mandibles and maxillae with deciduous premolars (younger than 3.5 years) and those with permanent fourth premolars or third molars (older than 3.5 years); Silver 1969. Crown height was measured and an absolute age established according to Levine (1982).

437 The maximum proportion, since animals with fused early-fusing epiphyses are not necessarily adult.

438 Chaplin 1971, 131.

439 The size of the age data sets is not the only factor influencing their value. When primary data were not included in the publication, age data could not be used.

440 E.g. Filean 2006, 361-362.

data are not corrected. The reason for that is that there are so many biases affecting the data set that it is impossible to correct for all of them; only correcting for one bias may distort the data set even more. A final problem is related to sample size. Since the data are divided into several categories, each category needs enough data. In some cases, even in larger assemblages, the number of epiphyses in the youngest age category is too low to calculate a percentage.[441] Since the percentages of killed animals in the following categories all depend on the percentage killed in the youngest category, the data set then becomes practically useless. It is possible to combine the youngest with the next age category and calculate a percentage for this wider category, but this also affects the percentages in the following categories.

While the basic method follows Chaplin, the age categories and epiphyses used in this study are slightly different. Tables E4.3 to E4.6 show the age categories used here, and the epiphyses assigned to each age category.[442]

4.4 SKELETAL ELEMENTS

Skeletal element distribution is analysed in two different ways. First, skeletal elements were grouped into seven different categories or sections of the body: head and neck, rump, upper front limb, upper hind limb, lower limbs, phalanges and other. Table 4.1 shows the skeletal elements assigned to the different categories, and figure 4.1 shows the distribution for complete cattle and horse skeletons. Since the proportion of loose teeth is dependent on the degree of fragmentation and preservation of the assemblage rather than a reflection of human activities, they have not been taken into account. The two categories 'rump' and 'other' are not included in the analysis. The rump is disregarded because there is a problem with comparing data from different sites. Ribs and vertebrae are not consistently identified by everyone, and are therefore often underrepresented, while in fact they are present, but have been labeled as large or medium mammals.[443] Ribs and vertebrae are rich in meat, and can say much about food preparation and about where consumption took place. They form an important source of evidence at site level, but are less suitable for a regional comparison. Only assemblages with 50 or more fragments for the five categories were included.[444]

The animal bone assemblages included in this study will have suffered differentially from taphonomical processes. The taphonomical index can be used to assess the effect of taphonomy on an assemblage (see paragraph 4.1). Another way to determine whether skeletal element distribution is affected more by taphonomy or by human behaviour is to compare skeletal elements for cattle with those for horse. While horses were certainly butchered and consumed in some sites, this seems to have occurred less than with cattle. Furthermore, there is no evidence for horse consumption in towns and military sites. Horses were either sold as live animals or died locally. There is no evidence for the use of horse hides.[445]

441 An example is Nijmegen-Castra.

442 Based on Silver (1969) and Habermehl (1975).

443 A survey among Dutch zooarchaeologists carried out in November 2011 indicated that ribs especially are identified by some but not by others.

444 Although in this case it may have been better to use the total weight per category rather than the number of fragments, these data were unavailable for most assemblages.

445 According to W. Groenman-van Waateringe, horse leather has never been found in Roman contexts. Lecture at Workshop 'Calculations in Archaeo(bio)logy' in Augst, 20-21 January 2011.

Fig. 4.2. Superficial chop marks on cattle ribs from Geldermalsen-Hondsgemet.

A second method of analysing skeletal elements was used to assess processes of butchery and consumption. Zeder used a division of the leg bones into meat-bearing and nonmeat-bearing in her study of meat supply and distribution in early urban centres in the Near East. This is a simple way of providing insight into how carcasses were processed.[446] Although this division was based on sheep and goats, it will also work well for cattle, since their anatomy is very similar. An analysis of meat-bearing and nonmeat-bearing limb bones was carried out for the three main meat providers: cattle, sheep or goat and pig. A minimum of 100 fragments from limb bones was used to avoid biases caused by small sample size.

category	skeletal elements
head+neck	cranium, maxilla, mandibula, horncores, cervical vertebrae[447]
rump	thoracic and lumbar vertebrae, ribs
upper front	scapula, humerus, radius, ulna, carpal bones
upper hind	pelvis, femur, tibia, tarsal bones
lower limbs	metapodials
phalanges	phalanges 1, 2 and 3
other	sesamoid bones, caudal vertebrae, patella, fibula, sacrum, hyoid

Table 4.1. Different categories used in the analysis of skeletal elements in this study.

[446] Zeder 1991, 95-96. Meat-bearing: scapula, humerus, radius, ulna, pelvis, femur and tibia; nonmeat-bearing: metapodials and phalanges. In a complete skeleton, the proportion meat-bearing – nonmeat-bearing is 33-67 %.

4.5 BUTCHERY

The analysis of butchery marks in this study is restricted to cattle and horse. First, the percentage of butchery marks on cattle and horse bones is looked at, both per site and per period, to establish the normal range. Only assemblages with a minimum of 50 fragments of cattle or horse were included to calculate percentages for individual sites; for the total percentage per period, smaller assemblages were included. Next, where possible, the number of chop and cut marks were recorded separately, and were used to calculate a 'chop-cut ratio'. This gives an immediate impression of which of the two was more commonly used to butcher cattle and horses. Third, the type of chop mark (superficial versus chopped through) was investigated (figs. 4.2 and 4.3). This was based on the butchery code system developed by Lauwerier.[448] Finally, a detailed investigation of the type of butchery marks present on cattle and horse bones gives insight into how these animals were butchered. Unfortunately, few assemblages included detailed recording of butchery marks. The need for large assemblages in order to allow meaningful analysis further narrowed down the available data. Only one rural site and two consumer sites were considered suitable for a more detailed analysis of butchery.

Since cleavers are specifically associated with butchery, and typically used in Roman butchery,[449] an inventory has been made of these tools in the rural sites included in this study. Since not all sites have been (completely) published, they could not all be included. The presence and number of knives was also recorded, although knives may have been used for other tasks besides butchery.

4.6 BIOMETRICAL ANALYSIS

4.6.1 WITHERS HEIGHT

Analysis of withers height was limited to cattle, sheep or goat and horse, since pig is only found in larger numbers in the Late Roman period. Furthermore, pigs were slaughtered at a young age, which limits the number of measurements, since only bones with fused epiphyses were included. Withers heights were calculated from the greatest length of the long bones using standard factors.[450]

Despite the problems related to the use of withers height to trace developments in size, it was decided to include withers heights in this study. The main advantage of using reconstructed withers heights is that it is easy to understand the actual effect of a size increase: a 1 cm difference may be statistically significant, but would people have even noticed this? A further reason for including withers height is that for some assemblages, the only data available are calculated withers heights. This way, those assemblages can be included in the study. Finally, there is a tradition of using withers height in studies of the Roman Netherlands.

447 Since some cervical vertebrae can remain attached to the head during initial segmentation, elements from head and neck have been put into one category.

448 Lauwerier 1988.

449 Lepetz 1996, 139-142; Seetah 2006, 112.

450 Von den Driesch/Boessneck (1974) and Matolcsi (1970) for cattle, May (1985) for horse and Teichert (1975) for sheep.

Fig. 4.3. Cattle vertebra from Tiel-Passewaaijse Hogeweg showing both superficial chop marks and a chop through the bone.

4.6.2 LOG SIZE INDEX

Withers height focuses on just one dimension of an animal. Analysis is based only on bone lengths and ignores other measurements. Meat – an important economic product – output is not just related to height, but also to width. It is therefore important to consider width and depth measurements.[451] Furthermore, by investigating size changes for each dimension, it is possible to understand the cause behind the changes. A method that is applicable to length, width and depth measurements is the so-called log ratio technique. This is the most commonly used scaling technique.[452] It converts measurements to log data, by comparing them with standard measurements. It is not absolute size that is plotted, but rather the extent to which a certain measurement is smaller or larger than the equivalent standard measurement.[453] It is not so much the comparison against the standard that is of interest, although, depending on the choice of standard, this can be informative in itself. Instead, differences between samples with different dates or from different sites can be compared. Using log ratios rather than the measurements themselves has the advantage of making the most of small samples, by combining different measurements of the same species on the same scale.

Davis mentions several complicating factors that should be considered in biometric studies. Their effect on the data set for the Roman Dutch River Area has been assessed. First, observer error constitutes a real problem for the data set, since measurements were taken by different researchers. Hopefully, if there is an effect on the data, it has affected the pooled data per period in a similar way.

[451] Albarella 2002, 55-56.

[452] Albarella 2002, 57.

[453] Albarella 2002, 52; Meadow 1999.

Observer variation has to be considered as an explanation if there are differences between individual assemblages. Second, wild and domestic forms of species could occur in one assemblage. For cattle, this does not seem to be a major problem, since aurochs are so much larger than domestic cattle, and therefore easily recognised.[454] Moreover, in the Roman Dutch River Area, wild mammals contributed so little to the animal bone assemblages that this should not affect the data very much. Next, age can affect data since mature animals are larger than immature ones. However, generally only fused bones were measured in the data set. Where it is stated specifically that a measurement is of an unfused bone (rarely encountered, and then with a specific reason, e.g. to illustrate the large size of a bone, even more so because immature, or to assess foetal or neonatal age), this measurement was not included. Finally, a shift in proportions of male and female animals can result in a change in size.[455] This is a problem for the data from the Dutch River Area. Ideally, scattergrams of different measurements or indices from the same element would provide insight into the distribution of the sexes. However, very few assemblages contained enough measurements to produce scattergrams.

The size of bones and teeth is affected by age, sex, type and environmental conditions, and not all elements are affected in the same way. Combining different measurements will enlarge the data set, but could also hide differences in size between different elements, and thus the cause for size variation. For the same reason, tooth and bone measurements should not be combined, because it is known that teeth are affected less by age, sex and environmental factors. Length, width and depth measurements should also be separated, if possible.[456] The data set for the Roman Dutch River Area included so few tooth measurements that they have not been considered.

A standard can be the measurements of a modern individual of known age and sex, the mean of a modern population of known sex and possible age, the mean of an archaeological assemblage, or an individual archaeological skeleton with known age and sex. When studying archaeological material, an archaeological standard may be the most appropriate, preferably from the same geographic region.[457] For this study, the standard that was used consists of the mean for measurements taken for Late Iron Age cattle from Geldermalsen-Hondsgemet (table E4.7). Using local Iron Age cattle seemed appropriate, since the study focuses on size change in cattle in the following period. Furthermore, this site is situated in the research area, and later assemblages from the site are part of this study. A drawback of using this archaeological standard was that the sample was small. However, the elements of which only a single measurement was available are generally the elements of which few survive archaeologically, and therefore they contributed minimally to the data set.

To calculate the log ratios, the log of the standard was subtracted from the log of each measurement: log (measurement) – log (standard). Negative values mean that a measurement is smaller than the standard, while positive values mean that a measurement is larger than the standard. Log ratios were only studied for cattle since these provide the largest data set and thus offer the best potential for studying developments in agriculture and interaction between producers and consumers. Measurements were taken according to Von den Driesch.[458] Only one measurement per dimension per element was used in the data analysis, but which one may differ between assemblages due to what was available. Unfortunately, only few measurements of depth were taken by most researchers. The Mann-Whitney U test was used to check the statistical significance of any observed differences; three different confidence levels are included in the tables: 95 % ($p<0.05$), 99 % ($p<0.01$) and 99.5 % ($p<0.005$). Box plots rather than histograms were used to display the data, as these are easier to compare and because I am mainly interested in differences between sites and developments over time.

[454] Davis 2008, 993.

[455] Davis 2008, 994.

[456] Albarella 2002, 54.

[457] Albarella 2002, 55.

[458] Von den Driesch 1976.

Although it is advised to use conventional analysis of measurements as well as scaling techniques,[459] this study is limited to log ratios and withers height, mostly because of the small sample sizes for individual measurements.

4.7 ARCHAEOBOTANY

The farmers in the Late Iron Age and Roman Dutch River Area all practised mixed farming. In a mixed farming system, animal husbandry and arable farming are both essential, and need and complement each other in various ways. Cattle especially provide manure that maintains soil fertility and are used to draw ploughs, improving soil quality. They can also be used to thresh cereals by trampling the oars. Arable fields provide grazing during fallow periods or as stubble after the harvest. Some crops may have been grown specifically as animal fodder. There is evidence from another region in the Netherlands that turnips and waste from processing crops, such as threshing waste from cereals or flax stems, was fed to livestock. Fodder was gathered on the salt marshes.[460] To fully understand animal husbandry, it is therefore important to also look at the evidence for arable farming. Not only did the two sides of farming complement each other, but together they provided a balanced diet, with cereal crops providing carbohydrates and protein, and meat and perhaps dairy products providing protein and fat. Root and leaf vegetables, herbs and fruits collected from wild bushes and trees added vitamins. New crops were introduced during the Roman period, and it will be interesting to see at what sites they are found.

The aim for this study was to collect information on botanical macro-remains for as many sites included in this study as possible. For the purpose of this study, a simple presence or absence of plant species was recorded. All information is taken from published reports; no raw data were analysed.[461] Wild plants have been included if it is likely that they were used for food, medicinal or other reasons. Also, weeds can sometimes provide an indication for the import of cereals. In a few cases, pollen provides additional information on crops. Local production is assumed for the crops that are common and which are already present in Late Iron Age sites, although this can rarely be proven.

A basic classification was used to group the plant species: cereals, pulses, (root or leaf) vegetables, herbs, medicinal plants, wild nuts and fruits, and other plants. It was not always clear whether some plants were cultivated or collected in the wild. Some crops have multiple uses, such as flax, which can be grown for its oily seeds (linseed) or its fibres (flax).

459 Albarella 2002, 55; Meadow 1999, 296.

460 Some of the evidence from Broekpolder dates to the Middle Iron Age, but there seems to have been continuity in livestock feeding. Therkorn *et al.* 2009, 140, 144, 147.

5. Rural settlements: animal husbandry and consumption

Since this chapter focuses on rural sites, the emphasis is on agrarian production, although the introduction of new types of food and technology (butchery tools) will also be discussed. This regional study aims not only to provide a general picture of animal husbandry in this region and time period and any developments occurring during the Roman period, but also to study the variation in response that occurred when local communities were faced with a market demand for agrarian products.

Since 45 of the 72 sites included in this study are rural settlements involved in agrarian production, the evidence for production is clearly stronger than the evidence for consumption. There are differences in the size of rural settlements, which vary from one to five or six farmhouses, but apart from that there is no clear hierarchy. Some sites have traditionally been interpreted as *villae*. Although the definition of a *villa* is inherent to its function as a large-scale agrarian production unit, interpretations for the Dutch River Area are invariably based on the size and lay-out of structures and the style of construction (stone, tiled roofs, other 'Roman' elements).[462] For this study, *villa*-like settlements are grouped with other rural sites, since they are all agrarian production units. We shall see whether agrarian production differs from ordinary rural sites. The same applies to several sites with a possible military connection. Before we look at the data from Roman sites, it is necessary to discuss farming in the Late Iron Age, to gain some understanding of the agrarian situation before the Roman occupation.

5.1 Farming in the Late Iron Age

5.1.1 Late Iron Age society and surplus production

The Late Iron Age economy in the research area was an agrarian subsistence economy. Mixed farming was practised, with nearly everyone involved in farming the land and looking after livestock.[463] The pastoral side of farming seems to have been especially important, and can be related to the greater suitability of the landscape for animal husbandry (plenty of fertile grassland for grazing) than for cereal farming (suitable arable land limited due to risk of flooding). The so-called pastoral ideology is reflected by the sharing of living space by man and animal.[464]

Some elements of Late Iron Age society may have predisposed it for a relatively easy transition to market production. In Southern Britain, conspicuous consumption and elite/client systems led to the production of a surplus of food. Evidence for this is seen in large storage buildings (for instance in Gorhambury and perhaps also Fishbourne), which may have been under the control of an elite, massive earthworks and a high proportion of drinking vessels.[465] Roymans argued that cattle played a role in exchange systems in mainland Northwestern Europe. His arguments are based on the distribution of the byrehouse, high proportions of cattle in the same area, the distribution of coins in the Late Iron Age, literary sources and ethnographic parallels.[466] A recent study on Late Iron Age animal husbandry

461 Chapter 2 includes some information on archaeobotany for each site. Archaeobotanical data are further discussed in paragraph 5.8.

462 Hulst 1978; Hulst 1980; Van der Feijst/Veldman 2012.

463 Roymans 1996, 44.

464 Roymans 1996, 51-55; 1999, 293.

465 Creighton 2006, 55-61, 154-155.

466 Roymans 1996, 47-55; 1999, 292-294.

in the Netherlands tested this hypothesis and concluded that it is supported by the zooarchaeological data.[467] First, there is an increase in cattle proportions in the Late Iron Age in the research area. Second, slaughter ages of cattle also increase in the Late Iron Age, with a majority reaching adulthood. This suggests that secondary products were more important than meat. With no evidence for dairying, these secondary products consisted of manure and power and could suggest intensification in arable farming. Intensification can perhaps be related to the migration of the Batavians to this region, which could have caused a population increase. However, an alternative explanation is that the role of cattle in exchange systems arose at this point or increased in importance.[468] Keeping larger herds than required for subsistence – since cattle represented wealth – would mean that a surplus of cattle was readily available.

These factors contributed to the ease with which surplus production was accomplished once a market became available. The particular nature of society and economy in the research area meant that a surplus of livestock, especially cattle, was easier to accomplish than a surplus of cereals.

5.1.2 Zooarchaeological data from Late Iron Age sites in the Dutch river area

Species proportions and numbers of fragments for assemblages from seven Late Iron Age sites are presented in figure 5.1 and table E5.1. Cattle is the main species, with proportions ranging from 49 to 74 %, followed by sheep or goat, with proportions between 12 and 33 %. Horse and pig are less frequent, with proportions exceeding 10 % for horse only found at Tiel-Oude Tielseweg and Odijk-Singel West/Schoudermantel, and for pig in Tiel-Passewaaijse Hogeweg.

The epiphyseal fusion data suggest that a large proportion of cattle reached adulthood (65-72 %).[469] This suggests that products of the living animal, such as traction and manure, were most important. However, the mandibular data suggest a focus on meat in Tiel-Passewaaijse Hogeweg and Geldermalsen-Hondsgemet. Slaughter peaks for sheep/goat are found between 2 and 3.5 years, which suggests a mixed exploitation for meat and wool.[470] There is some variation in the representation of the different body parts for cattle and sheep, but these are most likely caused by differences in taphonomy, and not by deliberate selection or processing of meat, hides or horn. The percentage of phalanges is much lower for sheep than cattle (0-5 % compared to 5-10 %), but this can easily be explained by their smaller size. The withers height for cattle ranges from 98 to 117 cm, with an average of 109 cm.[471] For sheep, the seven calculated withers heights vary from 52 to 64 cm, with an average of 58 cm, and for horse, the range is 108 to 144 cm, with an average of 126 cm.[472]

467 Van Dijk/Groot 2013.

468 The role of cattle in exchange systems has also been suggested for Early Neolithic Switzerland, where keeping cattle does not make sense from an agricultural/economic point of view, since labour costs far outweighed the benefits. Ebersbach 2002.

469 Van Dijk/Groot 2013, 181, 193, table 5.

470 Van Dijk/Groot 2013, 181.

471 24 of the 28 measurements for cattle are from Geldermalsen-Hondsgemet. The measurements from Odijk fit well with the average, but the measurements from the two sites in Tiel are smaller: 98 and 105 cm.

472 7 of the 12 measurements for horse are from Geldermalsen-Hondsgemet. Three of the four withers heights from the sites in Tiel are much larger than the average.

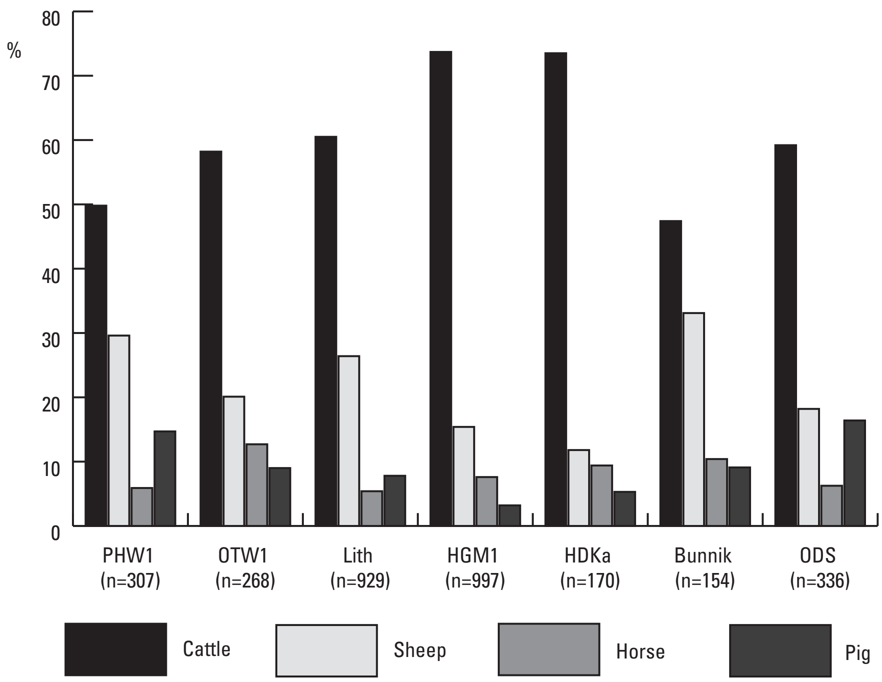

Fig. 5.1. Proportions for the four main domesticates for Late Iron Age assemblages, based on the number of fragments, per assemblage.

5.1.3 ARABLE FARMING IN THE LATE IRON AGE

Despite the ideological and social importance of cattle, cereals may have been more important as food.[473] The main cereals cultivated in the research area during the Late Iron Age are barley and emmer wheat. Oat is found but was probably a weed and not cultivated. Other crops are pulses such as Celtic bean and oil crops such as flax. Crops were grown at a subsistence level, without structural surplus production.[474]

5.2 TAPHONOMY

Taphonomy was studied for 40 assemblages from 24 rural sites. The percentages of butchery, gnawing and loose teeth for cattle together lead to a taphonomical index (table E5.2). The index for the studied assemblages ranges from 3 to 9, and has an average of 5.9. None of the assemblages seem to have suffered severely from the effects of taphonomical processes.

The size of the assemblage, the extent of sieving and the size and nature of the excavation lead to an index of representativeness. The extent to which feature fills have been sieved varies. It is often difficult to make out from reports how much has been sieved.[475] For Geldermalsen-Hondsgemet, for instance, fills from a large number of features were sieved, but these samples were only scanned for the presence of bird and fish remains. However, the sieved samples from this site contained very few larger

[473] Roymans 1996, 55.

[474] Kooistra 2009c, 5-7; Roymans 1996, 49-51.

[475] Because of the difficulties in assessing the extent of sieving and the proportion of a site which was excavated, the index of representativeness should be seen more as a subjective impression rather than as an accurate figure.

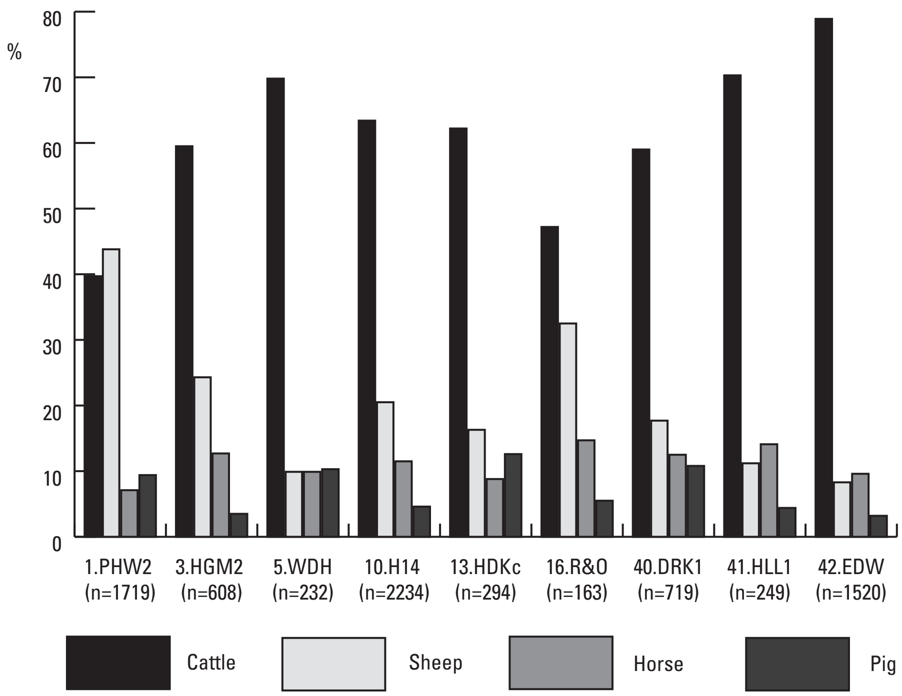

Fig. 5.2. Proportions for the four main domesticates for the Late Iron Age/Early Roman transition, based on number of fragments, per assemblage. See table 2.1 for an explanation of the site codes and fig. 2.1 for their location.

bones (such as cattle phalanges), since hand-collecting of bones was carried out before sieving. The index of representativeness for the studied assemblages ranges from 5 to 11, with an average of 8.7. The impact of assemblage size, lack of sieving and nature of the excavation is significant. This could have results for the skeletal element distribution, for instance where smaller fragments are underrepresented or where special activities were carried out in certain zones of the site.

What complicates matters is that assemblages with a low taphonomic index may have a high index of representativeness or vice versa. Since adding up the two indices evens out these differences, this has not been done. The indices will be taken into account in paragraph 5.5. The average bone weight varies from 8 to 106 g, but a figure between 10 and 40 g is most common (table E5.2).

5.3 SPECIES PROPORTIONS

Among the 45 rural assemblages is one assemblage with a general Roman date. The assemblage from Houten-Tiellandt is large, with over 1000 fragments for the four main domesticates, and potentially valuable for a regional study. Unfortunately, because of the wide date range, any developments occurring during the Roman period are obscured. One of the reasons for including this assemblage and mentioning it here is that it was an important study when first published; it has also influenced ideas about animal husbandry in the Roman Netherlands.[476] Second, this assemblage proves the point that zooarchaeological analysis is only really worthwhile when the archaeological features have been or will be analysed and published, and when the site can be dated accurately. The main species in Houten-Tiellandt is cattle with 66 %, followed by sheep/goat and horse with 14 %.

[476] Laarman 1996a.

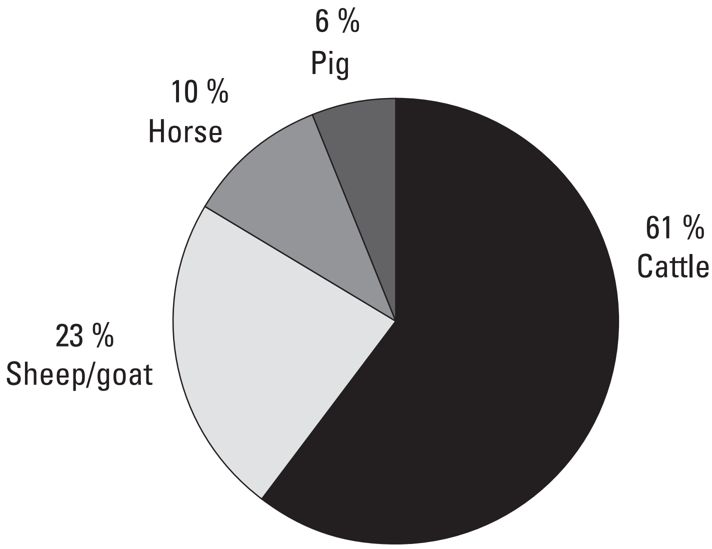

Fig. 5.3. Proportions for the four main domesticates for the Late Iron Age/Early Roman transition, based on number of fragments, for nine sites combined. Total number of fragments is 7254.

5.3.1 Sheep or goat?

The majority of fragments from sheep or goat found in archaeological sites cannot be attributed to one species with certainty. For the rural sites in the research area, 206 fragments were identified as sheep (95 %) and only 11 as goat (5 %) (table E5.3). This fits well with other data for the northwestern provinces.[477] Since goats are so strongly outnumbered by sheep, it seems justified to base the interpretations of this study on the assumption that herds consisted mostly of sheep.

5.3.2 Transition Late Iron Age to Early Roman period

Nine assemblages have a date spanning the Late Iron Age and Early Roman period (fig. 5.2; table E5.4). Handmade pottery from this period is notoriously difficult to assign to either the Late Iron Age or the Early Roman period.[478] Apparently, there were also no clear changes in settlement structure or building style that allowed more precise dating. Cattle is the most common species in all sites but one: Tiel-Passewaaijse Hogeweg. At this site, sheep is the animal with the highest percentage, followed by cattle. Sheep is also of relatively high importance in Geldermalsen-Hondsgemet and Geldermalsen-Rijs & Ooyen. In the other sites, the percentage of sheep is lower than 20 %. Horse ranges between 7 and 15 %, and pig between 3 and 13 %. Fig. 5.3 shows the combined data for this period: cattle is clearly the main species, followed by sheep.

5.3.3 Early Roman period

Fourteen assemblages have a secure Early Roman date, although in two cases the date overlaps slightly with the Middle Roman period (up to A.D. 100; fig. 5.4; table E5.5). The proportion of cattle is vari-

[477] Lauwerier 1988, 131: 8 % goat; Lepetz 1996, 86: 6 % goat; Luff 1982, 261; Maltby 2010, 158: 4 % goat; Peters 1998, 93.

[478] Vos 2009; Groot *et al.* 2009.

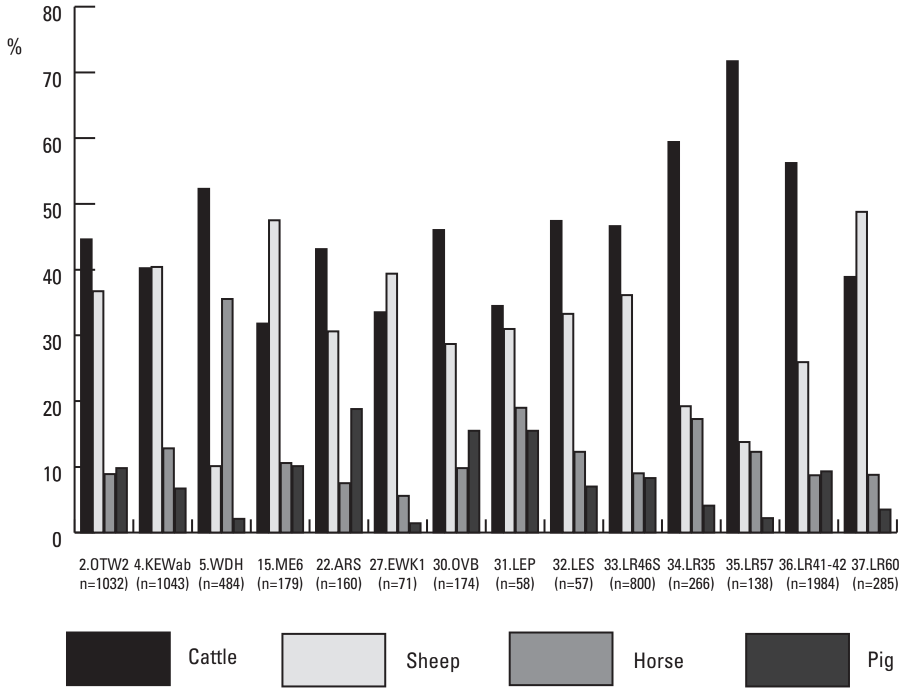

Fig. 5.4. Proportions for the four main domesticates for the Early Roman period, based on number of fragments, per assemblage.

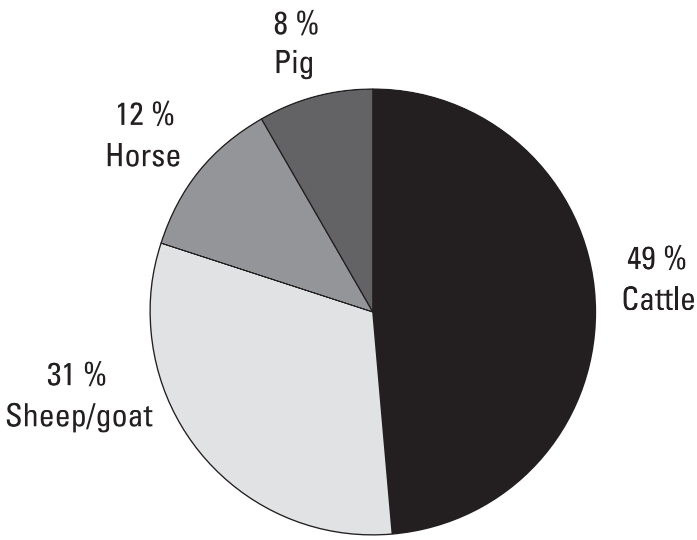

Fig. 5.5. Proportions for the four main domesticates for the Early Roman period, based on number of fragments, for 14 sites combined. Total number of fragments is 6731.

able, with percentages ranging from 32 to 72 %. Generally, sheep has relatively high percentages (ranging from 20 to 40 %). Also, the proportion of horse is generally low (around 10 %). The proportion of pig is also low in most sites, with percentages of 10 % or less. The combined data show that the main development in the Early Roman period compared to the transitional Late Iron Age/Early Roman period is an increase in sheep by 8 %, minor increases in horse and pig (2 %), and a corresponding decrease in cattle (fig. 5.5).

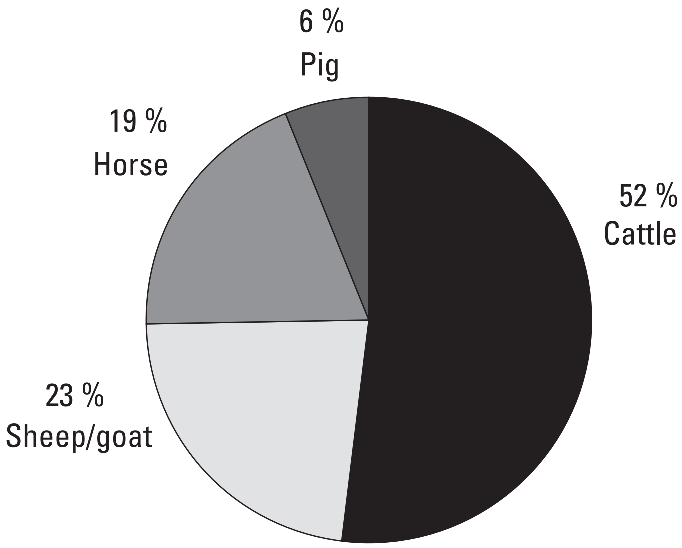

Fig. 5.6. Proportions for the four main domesticates for the transitional period from the Early to Middle Roman period, based on number of fragments, for 13 sites combined. Total number of fragments is 5556.
Legend on the right will be removed in final version

5.3.4 TRANSITION EARLY TO MIDDLE ROMAN PERIOD

Thirteen assemblages have a transitional date of Early to Middle Roman (table E5.6).[479] The percentage of cattle ranges from 34 to 70 % (fig. E5.1). Four sites have percentages of sheep exceeding 20 %, and six assemblages have percentages of horse higher than 20 %. Compared to the Early Roman period, the combined data for these sites show a smaller proportion of sheep and a higher proportion of horse (fig. 5.6).

5.3.5 MIDDLE ROMAN PERIOD

This is the period for which we have the most data (table E5.7). This is not surprising, since this is when settlement density in the Dutch River Area reached its highest point. The problem with using the standard chronology for the Roman Netherlands is that while the Early and Late Roman periods cover 70-80 years, the Middle Roman period covers 200 years. Furthermore, somewhere in this period, a significant development (an increase in the proportion of horse) occurs in many settlements. Broad dates make it impossible to date this development. I have previously stated that the increase in horse started around A.D. 100.[480] We have already seen that there are exceptions: in Wijk bij Duurstede-De Horden, for instance, the increase of horse is dated much earlier. Unfortunately, this development is difficult to pinpoint since the date of A.D. 100 falls in the middle of habitation phases for some of the sites with the best data, such as Tiel-Passewaaijse Hogeweg and Geldermalsen-Hondsgemet. In an attempt to overcome this problem, the Middle Roman assemblages have been divided into groups based on their chronology. Four overlapping periods have been distinguished: c. A.D. 70-150; after A.D. 100, split between the 2nd century alone, and a combination of 2nd and 3rd century; and after 150 A.D. The hope is that this will allow a more precise view of developments in animal husbandry. A fifth group contains assemblages with a general Middle Roman date and those that do not fit into the other four groups.

[479] Some of the fragments from this phase in Tiel-Passewaaijse Hogeweg can be assigned to either phase 3.1 or 3.2, but this reduces the total number of fragments. Therefore, both the total phase and the two subphases have been used here. See also table 5.5.

[480] Groot 2008a, 90; 2008b, 92.

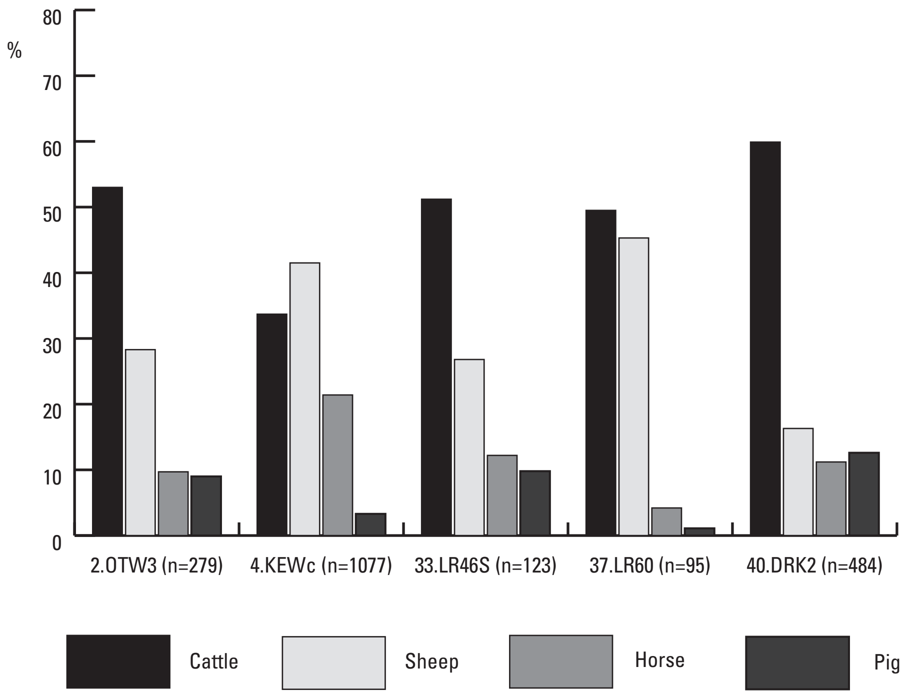

Fig. 5.7. Proportions for the four main domesticates for the Middle Roman period, A.D. 70-125/150, based on number of fragments, per assemblage.

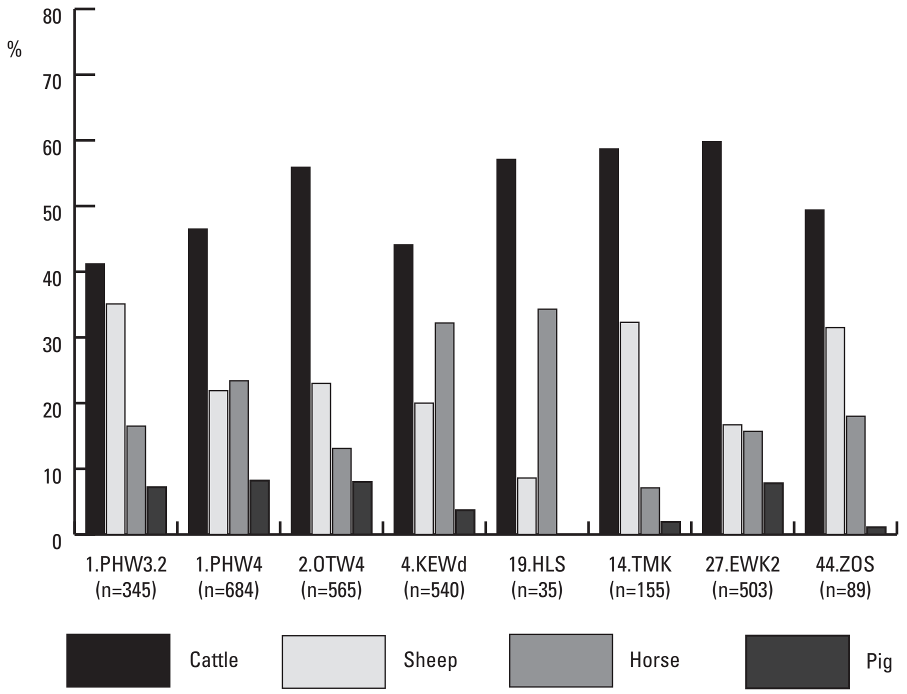

Fig. 5.8. Proportions for the four main domesticates for the Middle Roman period, c. A.D. 100-200, based on number of fragments, per assemblage.

Of the five assemblages dated between A.D. 70 and 150, cattle is the dominant species in four assemblages (fig. 5.7). In four assemblages, sheep has relatively high proportions (over 25 %); in Kesteren-De Woerd c, it is the dominant species. Only Kesteren-De Woerd c has a relatively high proportion of horse (> 20 %). Druten-Klepperhei 2 is the only assemblage with a relatively high proportion of

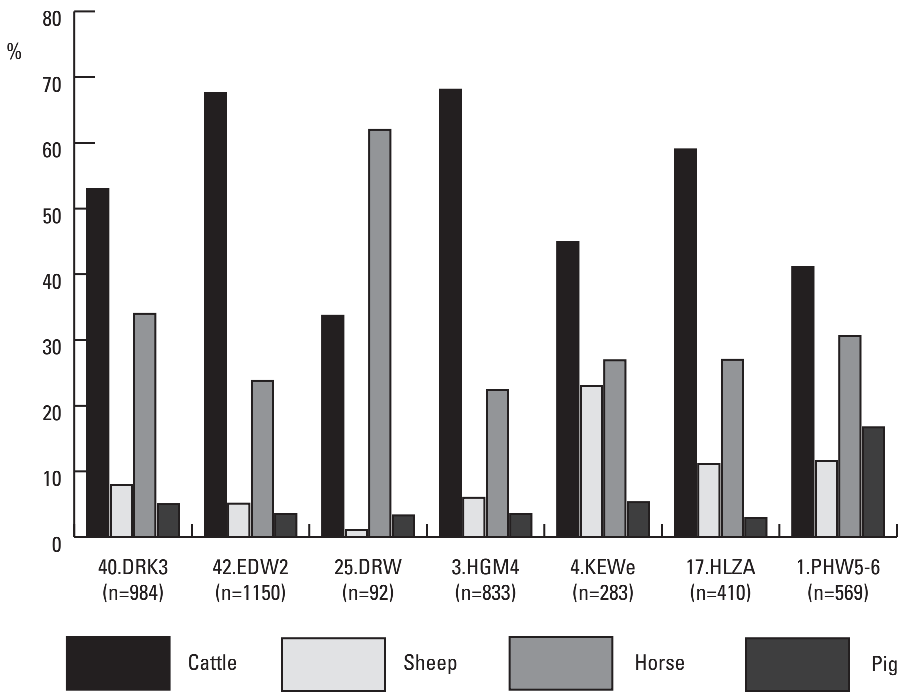

Fig. 5.9. Proportions for the four main domesticates for the Middle Roman period, c. A.D. 150-270, based on number of fragments, per assemblage. Sites arranged in order of chronology.

pig. Cattle is the most common species in all assemblages in the second group, dated between c. A.D. 100 and 200 (fig. 5.8). Three of the sites have proportions of sheep that exceed 30 %.

Three sites show relatively high percentages of horse (> 20 %). The percentage for pig is below 10 % in all sites. Cattle is also the dominant species in the third group of assemblages, with a broad date in the 2nd and 3rd centuries (fig. E5.2). Three assemblages have proportions of sheep exceeding 20 %. The proportion of horse is variable and ranges from 9 to 38 %. The fourth group covers the period A.D. 150-270. Cattle is the most common species in all but one assemblage (fig. 5.9). All assemblages except Kesteren-De Woerd e show low proportions of sheep (c. 10 % or less), and with the exception of Tiel-Passewaaijse Hogeweg 5-6, low proportions of pig (< 10 %). All assemblages have percentages of horse of over 20 %. The difference between the two assemblages from Druten, which are part of the same settlement, are probably due to the fact that the smaller assemblage comes from the periphery of the site, and may reflect some special activities. The last group contains four assemblages with a general Middle Roman date and three assemblages dated A.D. 70-200. Again, cattle is the dominant species (fig. E5.3). The assemblages Zaltbommel-De Wildeman site B and Tiel-Medel site 6 have similar species proportions with high percentages of sheep (both 28 %). Only one other assemblage has a percentage of sheep above 20 %. Three other assemblages – Houten-Overdam, Wijk bij Duurstede-De Horden and Zaltbommel-De Wildeman site A – also show very similar species proportions, with very high percentages of horse of around 35 %. The remaining four assemblages have comparatively low proportions of horse, ranging from 11.5 to 15 %. One of the assemblages, Arnhem-Schuytgraaf, shows a high percentage of pig (> 20 %). The contrast in the percentages of sheep and horse between the two assemblages from Zaltbommel-De Wildeman is remarkable.

The combined graph for all Middle Roman sites shows a decrease in sheep and an increase in horse, when compared to the Early Roman period (fig. 5.10).

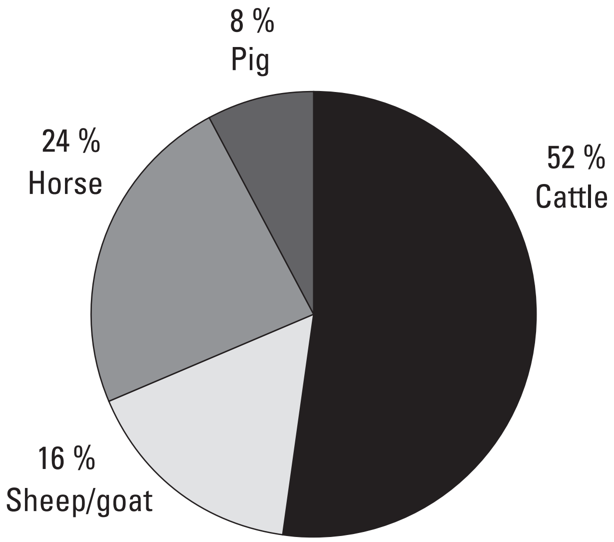

Fig. 5.10. Proportions for the four main domesticates for the Middle Roman period, based on number of fragments, for 29 assemblages from 27 sites combined. Total number of fragments is 15,706.

5.3.6 Dating the start of the increase in horse

The relatively high proportions of horse in many Middle Roman sites make it clear that this species played an important role in the agrarian economy of the Dutch River Area. However, it remains difficult to date the start of the increase in the significance of horses. For Tiel-Passewaaijse Hogeweg, for instance, the proportion of horse first exceeds 20 % in phase 4 (A.D. 130-220), but already increased from 10 to 16.5 % from phase 3.1 to phase 3.2 (around A.D. 100). Wijk bij Duurstede-De Horden is exceptional for its early start in horse breeding in the Early Roman period. Other assemblages with relatively high percentages of horse for the 1st century A.D. are Utrecht-LR35 (17 %) and Lent-Petuniastraat (19 %, but a small assemblage). Only one of the five assemblages dated in the first half of the Middle Roman period, before A.D. 125/150, shows evidence of a significant increase in horse: Kesteren-De Woerd c. At the other four sites, proportions of horse do not exceed the average for the Early Roman period of 12 %. Another exception is formed by Geldermalsen-Hondsgemet 3 (which overlaps with the last decades of the Early Roman period), where the percentage of horse is 20 %. Two of the assemblages dated to the 2nd century show somewhat higher percentages, but only one has a percentage of more than 20 %, and it is probably no coincidence that this assemblage (Tiel-Passewaaijse Hogeweg 4) has a later starting date compared to the other assemblages. All sites that can be dated confidently to after A.D. 150 have proportions of horse of over 20 %. It seems that this is when horses became of real significance in the Dutch River Area, although a gradual increase can be observed earlier in sites with a good chronology, such as Tiel-Passewaaijse Hogeweg and Geldermalsen-Hondsgemet.

5.3.7 Late Roman period

Two of the Late Roman assemblages are from phases overlapping the Early Middle Ages. They have been included here because of the relative paucity of data for the Late Roman period. The species proportions show some variation (fig. 5.11; table E5.8). Cattle is the dominant species in nearly all assemblages. All Late Roman sites show a low percentage of sheep, with a figure exceeding the 10 % only found for Arnhem-Schuytgraaf. Two assemblages have a relatively high proportion of horse. The proportion of pig ranges from 16 to 44 %, but the high figure is from a small assemblage and therefore perhaps less representative. Five of the eight sites have a percentage of pig just over 20 %.

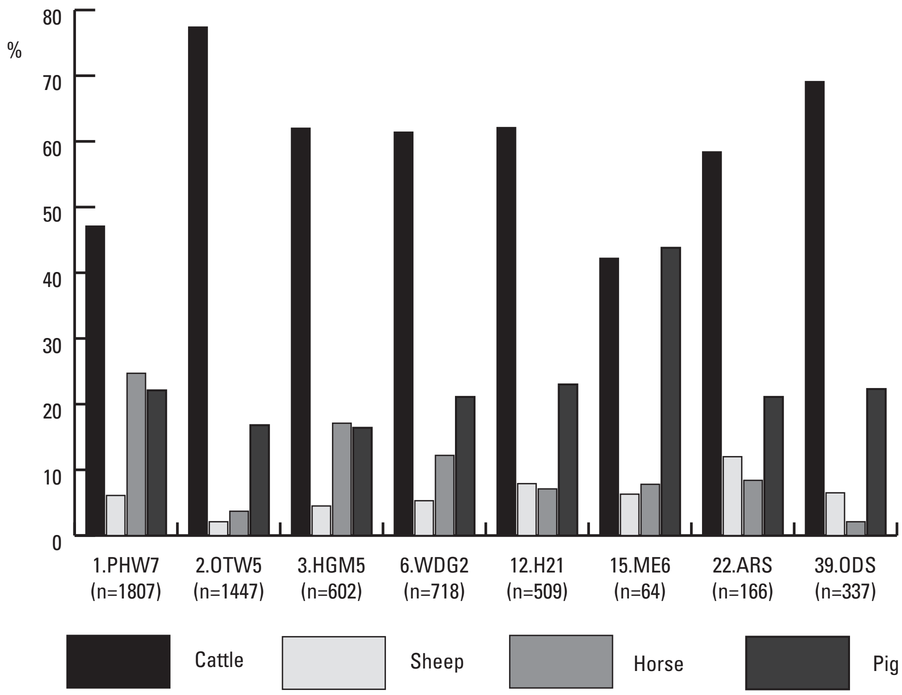

Fig. 5.11. Proportions for the four main domesticates for the Late Roman period, based on number of fragments, per assemblage.

When compared to the Middle Roman period, the combined data for the Late Roman period show a further decrease in sheep, a decrease in horse, and a corresponding increase in pig and cattle (fig. 5.12). The percentage of pig now exceeds 20 %, whereas it was of limited significance in earlier periods. Another typical find for Late Roman assemblages is a more significant contribution of wild mammals.

5.3.8 Wild mammals in the Late Roman period

An increase in the representation of wild mammals in Late Roman assemblages has been noted before.[481] Percentages of wild mammals in Late Roman sites in the Dutch River Area range from 1.0 to 5.7 %, with an overall proportion of 2.4 % (table E5.9). This is much higher than the overall proportion for the Late Iron Age/Early Roman and Middle Roman periods (tables E.5.10-12). However, when individual assemblages from the Early/Middle and Middle Roman period are considered, several do have a relatively high proportion of wild mammals, for instance Early Roman Heteren-Het Lage Land 1 and Middle Roman Druten-Klepperhei 3. Local differences in the environment could account for a higher availability of wild mammals around these sites, but that does not explain why nearby sites do not also show a higher percentage of wild animals. It could also be related to a personal preference for game. If hunting was seen as a high-status activity, a higher proportion of wild animals could be an indication for a higher status of the inhabitants. The *villa*-like settlement of Druten-Klepperhei clearly differs from the average rural settlement.

481 E.g. Lauwerier 1988, 144 for Nijmegen; Groot 2008a, 62 for Tiel-Passewaaij, although in one of the sites in Tiel the proportion starts to increase in the Middle Roman period.

	PHW7	OTW5	HGM5	WDG	H21	ME6	ARS	ODS	total
wild boar	7	4	1	13	1	1			27
red deer	12 (1)	17 (1)	5 (4)	9 (0)	16 (?)	1 (0)	10 (0)	2 (0)	63 (6)
elk				1 (0)	2				3 (0)
aurochs				1	2			2	5
brown bear	1			1					2
badger				1					1
wild cat				3					3
beaver	2			11	9			2	24
otter		1							1

Table 5.1. Number of fragments per species of wild mammal for the Late Roman period. Between brackets the number of fragments from antler, which is included in the total figures.

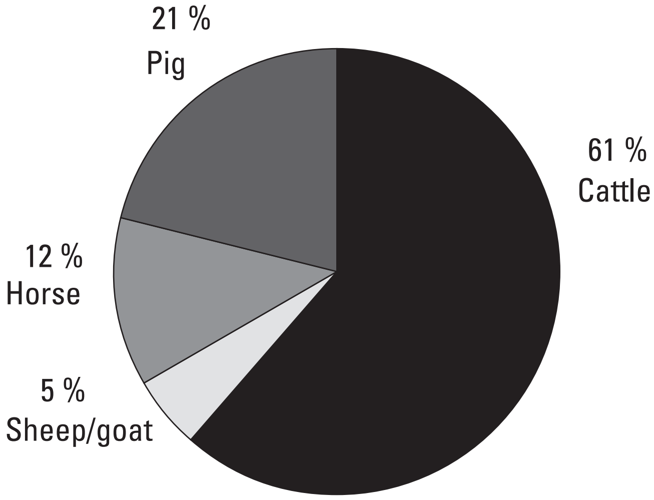

Fig. 5.12. Proportions for the four main domesticates for the Late Roman period, based on number of fragments, for eight sites combined. Total number of fragments is 5650.

The increase in the proportion of wild mammals in the Late Roman period may be related to an actual increase in the numbers of wild mammals in the Dutch River Area. As a result of a decrease in population, woodland had a chance to regenerate.[482] This would have provided more habitat for animals such as red deer and wild boar. An alternative interpretation is that the higher proportion of wild mammals is caused by the presence of a different ethnic group in the Late Roman period, with different traditions and attitudes to hunting.

Nine different species of mammal are represented in the Late Roman assemblages (table 5.1). Wild boar, red deer, elk and aurochs can be considered as prime meat game. Brown bear, badger, wild cat, beaver and otter are more likely to have been hunted for their fur, although their meat may have been eaten as well. The brown bear may have been seen as a threat to local inhabitants, but hunting such a powerful animal could also have proven a hunter's courage and skills. The large herbivores may have been seen as a threat to crops, and hunted for that reason. It is unlikely that red deer were hunted for their antlers. Antlers can easily be collected after they have been shed, and the predominance of shed antlers in archaeological sites shows that this was commonly done.

[482] Bakels 1996; Bunnik 1999; Kalis *et al.* 2008; Kooistra 2007, 210; Lauwerier 1988, 144; Steenbeek 1990.

5.3.9 CHICKEN AND SEASHELLS

5.3.9.1 Chicken

Chicken was introduced to the research area in the Roman period. Therefore, it is interesting to see how fast and how wide this species spread. A first possible problem with the data is that the presence of chicken may be dependent to some degree on whether sieving was carried out or not. On the other hand, there does not seem to be a correlation between the presence or absence of chicken in rural sites in the Dutch River Area and the extent of sieving. A second problem is that chicken bones are much more fragile than those of mammals, and may have suffered more from taphonomical processes. The proportion of chicken bones has been calculated out of the total for chicken and mammals, but that is only intended to show the relative abundance of chicken in the different assemblages. It is specifically not intended to show the abundance in comparison to mammals.

The presence or absence of chicken bones was scored for all rural sites. Chicken was present in 20 assemblages from 14 rural sites (out of a total of 45 sites, so 31 %; table E5.13). The numbers and percentages of chicken bones are very low: there are no assemblages with a percentage of chicken over 1 %. In four cases, chicken bones were dated to the Early Roman period. It is questionable whether the find from Houten-Schalkwijkseweg should also be seen as Early Roman, since there has been some discussion about the date of this site.[483] These early chickens indicate early contacts between the inhabitants of rural sites and the Roman army or townspeople. The absence in Geldermalsen-Hondsgemet is interesting. This is a modern, large excavation, where a large number of animal bones with good preservation were collected. Samples from 45 features were sieved and scanned, but yielded very few bird bones. None of the bird bones from this site are from chicken. Although only three rural cremation cemeteries from the research area are known well enough to say something about the species used in funerary ritual, it is interesting that chicken is found in all three cemeteries.[484] Perhaps chicken was adopted more readily in funerary ritual than in the kitchen.

5.3.9.2 Seashells

Seashells are interesting for two reasons. First, they tell us something about food consumption and food preferences. Second, since the research area is not situated on the coast, they must have been transported to the rural sites, and can therefore say something about supply networks. Seashells may be underrepresented in this study because it was not always clear from the publications whether they were collected or not, and whether they were analysed by the zooarchaeologist. Taphonomical processes affect different species in different ways: oysters are strong and will withstand trampling, whereas mussels are fragile and therefore easily fragmented.

The same approach was used as for chicken. The presence or absence of shellfish was recorded, as well as the number of fragments compared with the total number of fragments for the four main mammals and shellfish. Only seashells were recorded, because land and freshwater species of mollusc may have lived naturally in or around the archaeological sites.[485] Seashells were present in six assemblages from five rural sites (11 %; table E5.14). Only one species is represented: the oyster; the proportion of seashells out of the total number of fragments ranges from 0.05 to 2.28 %.

[483] Vos 2009, 158.

[484] Esser *et al.* 2010; Groot 2008a; Van Dijk 2011b.

[485] When land molluscs are found outside their natural habitat, they are likely to have been consumed. One example is the edible snail (*Helix pomatia*), which was found in Valkenburg and the *villa* of Hoogeloon. Kooistra/Groot 2014; Laarman 1987.

5.3.10 WILD BIRDS AND FISH

Remains of wild birds were present in half of all sites, and slightly below half of all assemblages (table E5.15). When divided into periods, there seems to be an increase in the number of assemblages with birds in the Middle Roman period. At least 23 species are represented with a total of 119 fragments. Ducks and geese are well represented, both occurring in 17 assemblages.[486] Members of the crow family are also rather common: they are found in eight assemblages, with a variety of species: carrion crow (*Corvus corone*), raven (*Corvus corax*), magpie (*Pica pica*), rook (*Corvus frugilegus*) and Eurasian jay (*Garrulus glandarius*). While some of these species may have scavenged near human habitation or may have been hunted for feathers, ravens and crows seem to have had a ritual meaning in the Iron Age and Roman period.[487] Birds of prey and owls were present in four assemblages: white-tailed eagle (*Haliaeetus albicilla*), cinereous vulture (*Aegypius monachus*), eagle owl (*Bubo bubo*) and long-eared owl (*Asio otus*). The first two may have come close to human habitation to scavenge for food.[488] Three large species of bird were found in three assemblages: grey heron (*Ardea cinerea*), crane (*Grus grus*) and swan (*Cygnus* sp.). The final species are medium-sized or smaller: coot (*Fulica atra*), cormorant (*Phalacrocorax carbo*), black-tailed godwit (*Limosa limosa*), common snipe (*Gallinago gallinago*), golden plover (*Pluvialis apricaria*) and an unidentified small songbird. The lack of small bird species can be explained in two ways. First, systematic sieving of feature fills is rare in the rural sites discussed here (see table E5.2). If sieved samples are included, the mesh size will affect the size of the species that are found. It is not always clear from zooarchaeological reports what mesh size is used. Second, larger birds provide more food per animal and may have been preferred.

Fish remains were found in under a third of all sites and about a quarter of all assemblages (table E5.16). A total of 326 fragments was identified to species or family, with 11 species represented. Pike (*Esox lucius*) is by far the most common species, occurring in nine sites and 13 assemblages. Other species that are found several times are sturgeon (*Acipenser sturio*), wels catfish (*Siluris glanis*), bream (*Abramis brama*), perch (*Perca fluviatilis*) and tench (*Tinca tinca*). Found only once are houting (*Coregonus oxyrinchus*), common roach (*Rutilus rutilus*), European eel (*Anguilla anguilla*) and a member of the salmon family (Salmonidae). The above species are all freshwater or anadromous species, but one saltwater species was identified: the haddock (*Melanogrammus aeglefinus*). While the relative scarcity is certainly related to the lack of systematic sieving, in some cases fish were really absent. In the site Geldermalsen-Hondsgemet, for instance, fills from 45 features were sieved over 2 mm, and did not yield any fish remains.[489] The only fish fragment from this site was collected by hand. Archaeobotanical samples were sieved using a smaller mesh size, and only yielded a single fish fragment.

5.4 EXPLOITATION OF LIVESTOCK

Data on age and sex of slaughtered livestock are necessary to reconstruct exploitation practices.[490] Cattle are usually exploited for meat, milk or traction, which leads to mortality profiles with lots of young adults, a combination of calves and older cows, and older animals, respectively. Exploitation of sheep for meat or milk lead to similar mortality profiles as in cattle. Sheep can also be kept for their wool, in which case the animals are slaughtered at ages older than is optimal for meat, and equal ratios of

[486] Including greylag/domestic goose (*Anser anser/domesticus*), greater white-fronted goose (*Anser albifrons*), bean goose (*Anser fabalis*), mallard/domestic duck (*Anas platyrhynchos/domesticus*), wigeon (*Anas penelope*) and teal/garganey (*Anas crecca/querquedula*).

[487] Serjeantson/Morris 2011.

[488] Groot *et al.* 2011; Mulkeen/O'Connor 1997.

[489] Groot 2009a, 356, 358.

[490] See paragraph 3.2 for a more detailed discussion of the interpretation of age and sex data.

males and females are found. Missing age categories can be an indication for the removal of livestock to urban and military markets.

5.4.1 Sex determinations

The number of sex determinations for individual sites or assemblages is so small that they had to be combined. Table 5.2 shows that cows are dominant from the Late Iron Age until the Late Roman period, when equal ratios of males and females are found. Males include bulls and oxen; while oxen were especially important in the Roman Empire for traction, this does not show in our data. Sex determinations for cattle are mainly based on the shape of the pubic bone, followed by the shape of the metapodials and horncores. For pigs, females are more common during the Late Iron Age than males (table 5.3). In the Early and Middle Roman periods, the proportions of males and females are similar. In the Late Roman period, males are more common. For sheep and horse, the sample size was too small to allow an analysis over time. Ewes are more common than rams or wethers (table 5.4). For horse, the opposite applies, with more male horses being present among the animal bones from rural sites than mares (table 5.4).

period	n male	n female	total	% male	% female
Late Iron Age	0	15	15	0	100
Early Roman	2	15	17	12	88
Middle Roman	4	30	34	12	88
Late Roman	9	9	18	50	50
all periods	16	74	90	18	82

Table 5.2. Sex determinations for cattle from rural sites, based on the shape of the pubic bone. See table E5.17 for sex determinations per site.

period	n male	n female	total	% male	% female
Late Iron Age	3	8	11	27	73
Early Roman[491]	11	13	24	46	54
Middle Roman[492]	23	20	43	54	46
Late Roman	52	14	66	79	21
all periods	131	103	234	56	44

Table 5.3. Sex determinations for pigs from rural sites, based on the morphology of the canines. See table E5.18 for sex determinations per site.

species	n male	n female	total	% male	% female
sheep	7	11	18	39	61
horse	41	14	55	75	25

Table 5.4. Sex determinations for sheep and horses from rural sites, based on the shape of the pubic bone for sheep and the presence or absence of canine teeth for horse. The determinations for sheep are all from the Late Iron Age to Middle Roman period, and those for horse from the Late Iron Age to Late Roman period. See tables E5.19 and E5.20 for sex determinations per site.

491 Including Late Iron Age/Early Roman Tiel-Passewaaijse Hogeweg 2.

492 Including Tiel-Passewaaijse Hogeweg 3, Geldermalsen-Hondsgemet 3 and Druten-Deest, which include the last decades of the Early Roman period.

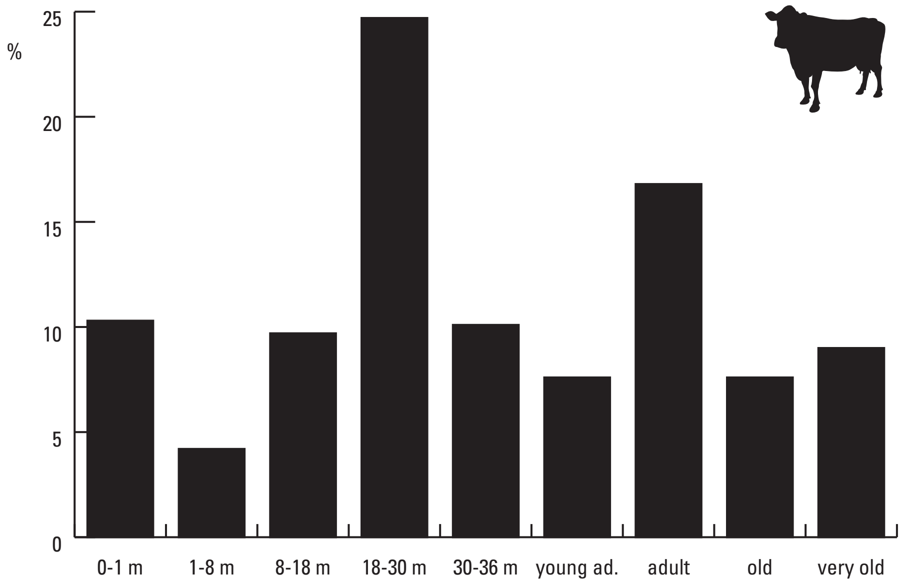

Fig. 5.13. Combined mortality profile for cattle from 11 Early Roman assemblages (some with overlap with the Late Iron Age), based on mandibular tooth eruption and wear (percentages out of the total number of aged mandibles, n=245).

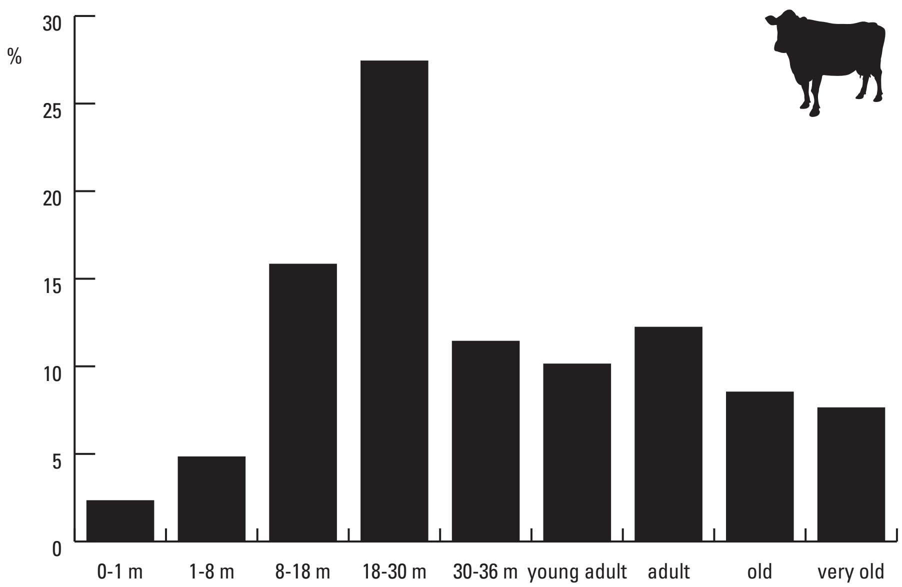

Fig. 5.14. Combined mortality profile for cattle from eight assemblages from the transitional period from the Early to Middle Roman period, based on mandibular tooth eruption and wear (percentages out of the total number of aged mandibles, n=184).

5.4.2 CATTLE

5.4.2.1 Mandibular tooth eruption and wear

Since only two assemblages from the Early Roman period provided enough data, the transitional phase Late Iron Age/Early Roman period has been included here. The combined data graph for 11 sites from this period shows that 10 % of cattle are killed in their first month and 25 % of cattle between 18 and

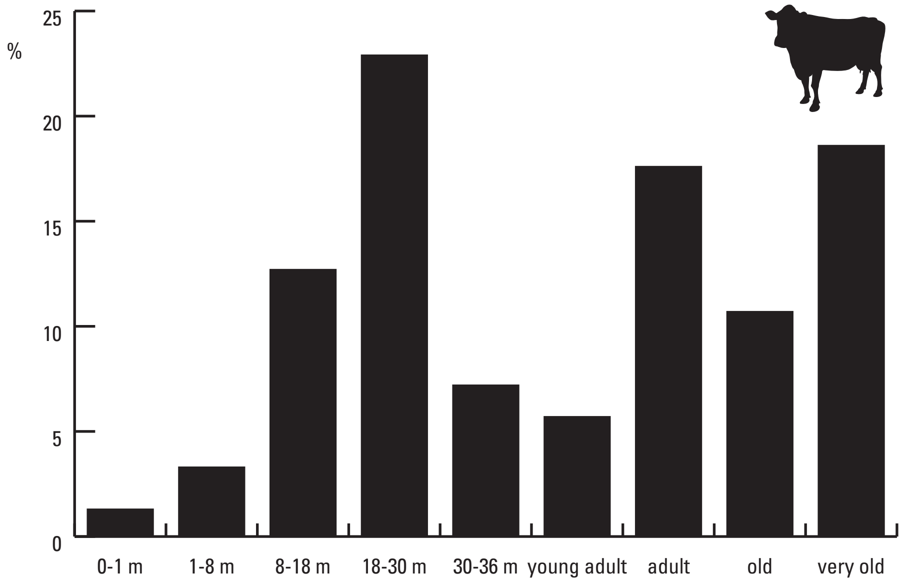

Fig. 5.15. Combined mortality profile for cattle from 17 Middle Roman assemblages, based on mandibular tooth eruption and wear (percentages out of the total number of aged mandibles, n=197).

30 months (fig. 5.13). 33 % live to adulthood. Five sites have yielded more than 10 aged mandibles; three of these sites show a clear slaughter peak between 18 and 30 months (fig. E5.4).

Some of the larger samples are dated to a transitional period overlapping the later Early and early Middle Roman period. Three assemblages cover the period A.D. 50-150, while the other three have broader dates of c. A.D. 0-200. All assemblages with the exception of Geldermalsen-Hondsgemet 3 show a slaughter peak between 18 and 30 months (varying from 25 to 39 %; fig. E5.5). The main peak for Geldermalsen-Hondsgemet 3 occurs in the category 'adult'. The proportion of cattle living into adulthood and beyond varies from 20 to 44 %. Druten-Deest is the exception with no cattle at all surviving into adulthood. Combined data for nine sites dating to this period show a slaughter peak of 27 % between 18 and 30 months (fig. 5.14). 28 % live to adulthood or longer.

For the Middle Roman period, cattle mortality could be analysed for seven sites. Four assemblages have slaughter peaks of 25 % or more between 18 and 30 months (fig. E5.6). Other peaks are visible in the age categories 'adult' and 'very old'. For six of the assemblages, 41-53 % of cattle reach adulthood or older ages. The combined data for 17 Middle Roman sites show a slaughter peak of 23 % between 18 and 30 months (fig. 5.15). 47 % reach adulthood, 19 % of which live on to a very old age.

The combined data for five Late Roman sites show that 45 % of cattle reach adulthood (fig. 5.16). The proportion of animals that live into old age is high: 24 %. There is still a slaughter peak between 18 and 30 months, but smaller than in previous periods. Three Late Roman sites have yielded more than 10 aged cattle mandibles. Wijk bij Duurstede-De Geer shows a peak for the category 'adult' (fig. E5.7). The age category with the highest proportion of slaughter for Geldermalsen-Hondsgemet 5 and Tiel-Passewaaijse Hogeweg 7 is 'very old'. Slaughter for meat at young age categories is rather high at Tiel-Passewaaijse Hogeweg, but spread over two age categories.

5.4.2.2 Epiphyseal fusion

To compare different sites, it was necessary to make a broad division in the data sets: Late Iron Age/Early Roman, Middle Roman and Late Roman. For the Late Iron Age/Early Roman period, the percentage of unfused epiphyses (and therefore the proportion of cattle killed before adulthood) ranges from 9 to 31 % (fig. 5.17). Most assemblages have percentages between 21 and 31 %. When all the data

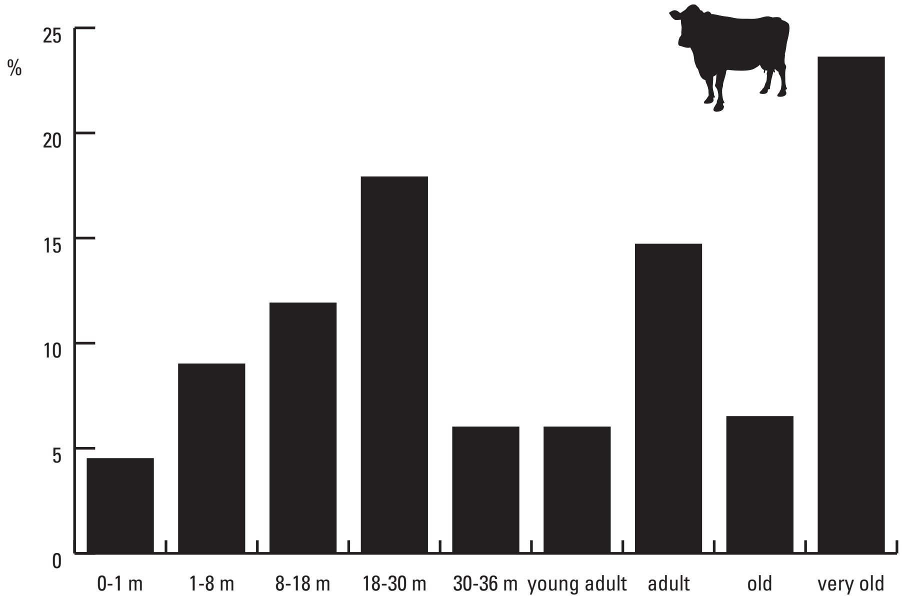

Fig. 5.16. Combined mortality profile for cattle from five Late Roman assemblages, based on mandibular tooth eruption and wear (percentages out of the total number of aged mandibles, n=67).

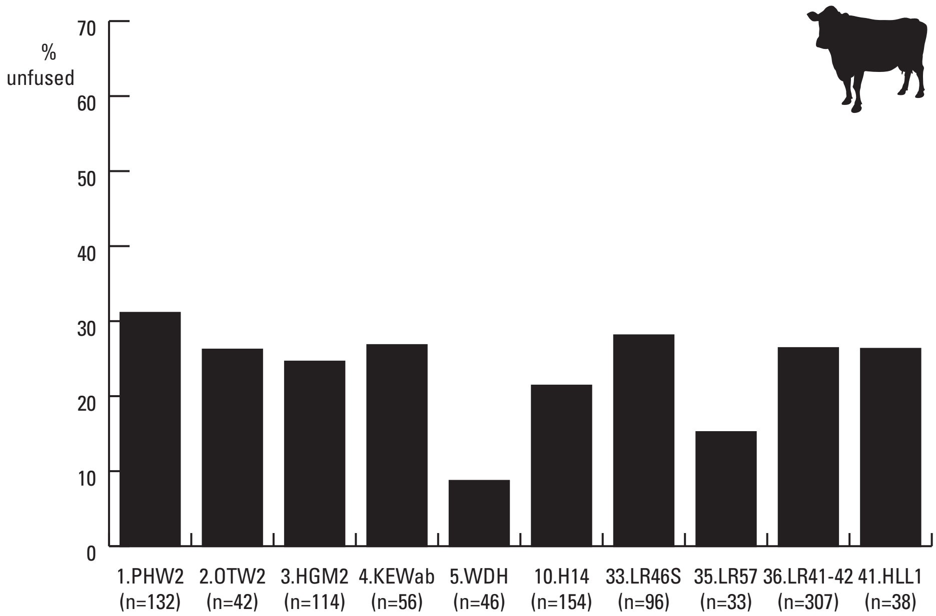

Fig. 5.17. Percentage of unfused epiphyses for cattle from Early Roman assemblages (some with overlap with the Late Iron Age).

are combined, the proportion of unfused epiphyses is 26 % (12 assemblages, n=1071). The mortality profiles for five individual assemblages give additional information on the age at which cattle were killed (fig. E5.8). 11-22 % of cattle were killed in the first two years. Geldermalsen-Hondsgemet 2 shows a slaughter peak between 2 and 3 years, and Tiel-Passewaaijse Hogeweg 2 has a slaughter peak between 3 and 4 years. The other three assemblages have slaughter peaks of adult cattle.

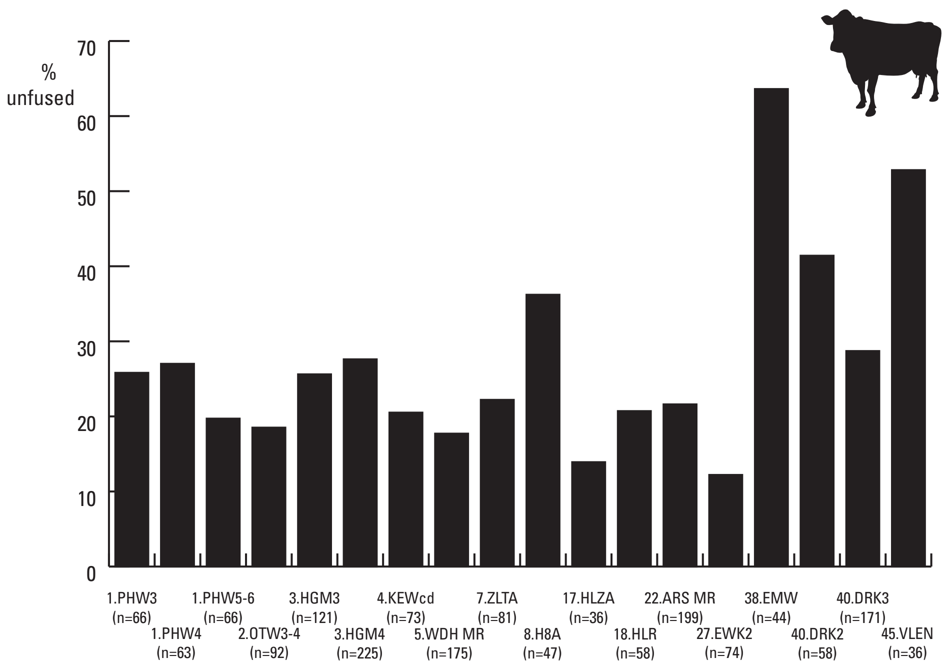

Fig. 5.18. Percentage of unfused epiphyses for cattle from Middle Roman assemblages.

For the Middle Roman period, which includes several assemblages with a date that slightly overlaps with the Early Roman period, the proportion of unfused epiphyses for cattle ranges from 12 to 64 % (fig. 5.18). Most assemblages have values between 18 and 29 %. The combined data give a proportion of unfused epiphyses of 26 % (21 assemblages, n=1762). Both this average and the range of percentages for individual sites are not much different from the Early Roman period. The mortality profiles show that up to 19 % of cattle were killed in their first year, and very few (0-7 %) in the second year (fig. E5.9). All assemblages have slaughter peaks of adult cattle.

The proportion of unfused epiphyses for Late Roman assemblages varies from 16 to 39 % (fig. 5.19). The combined data give a figure of 26.5 % (7 assemblages, n=863). The mortality profiles show differences between Tiel-Passewaaijse Hogeweg 7 and the other three assemblages (fig. E5.10). In Tiel-Passewaaijse Hogeweg, 32 % of cattle were killed in the first year, compared to 5-12 % in the other two sites. All sites show slaughter peaks of adult cattle, but the proportion of cattle surviving to adulthood is much lower for Tiel-Passewaaijse Hogeweg 7 than for the other sites.

5.4.2.3 Developments within sites

Tiel-Passewaaijse Hogeweg and Geldermalsen-Hondsgemet both have large assemblages and a chronology spanning the entire Roman period. Therefore, they are suitable for studying changes over time in mortality profiles. The Iron Age phases have been included here to trace long-term developments.

In Tiel-Passewaaijse Hogeweg, mortality profiles for cattle based on mandibles show a change in exploitation in the first half of the 2nd century (between phase 3 and 4-6; fig. 5.20). Before c. A.D. 140, cattle are mainly exploited for meat: a majority is slaughtered in the first three years of life, with a peak between 18 and 30 months (figs. E5.4 and E5.5). The sample for the Iron Age is small, but shows even higher slaughter rates of young cattle. In phase 4-6, the majority of cattle lives to adulthood. There is no clear slaughter peak for meat (fig. E5.6). The Late Roman period shows an increase in the slaughter of non-adult cattle. The data for epiphyseal fusion show a similar pattern as the mandibular data. From the Early to the Middle Roman period, slaughter of cattle in the youngest age categories

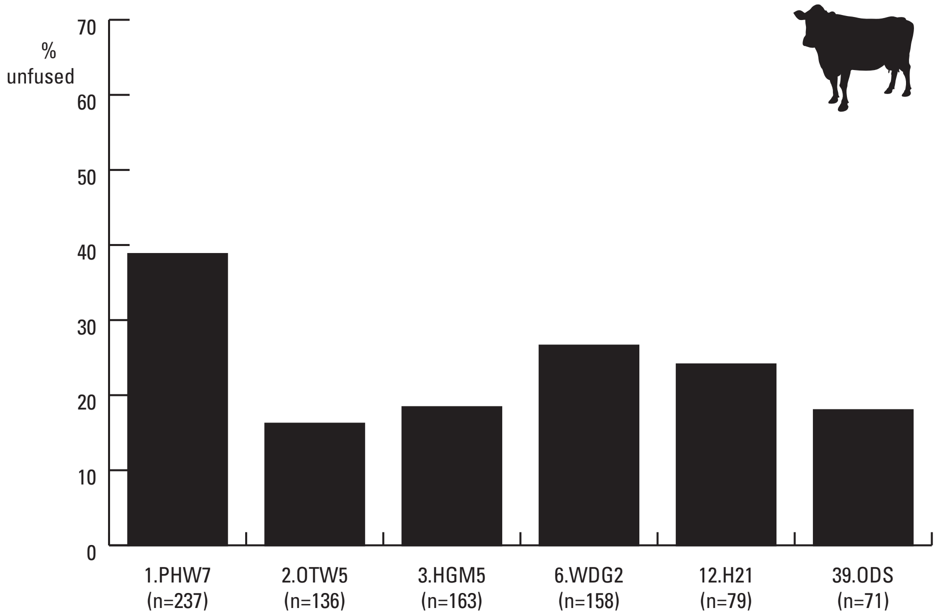

Fig. 5.19. Percentage of unfused epiphyses for cattle from Late Roman assemblages.

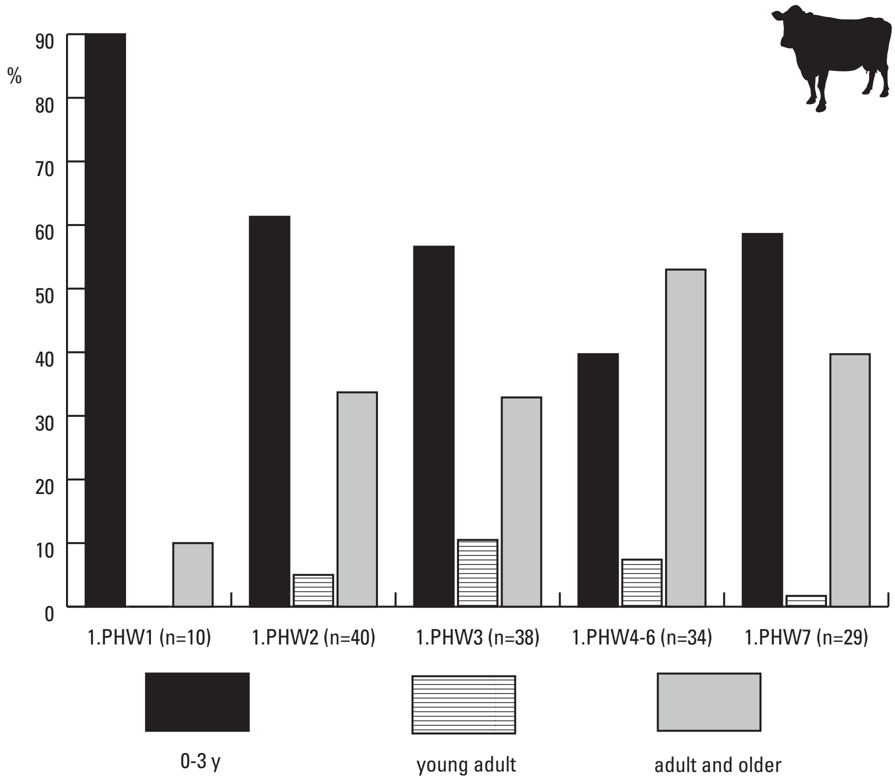

Fig. 5.20. Mortality profiles for cattle from Middle/Late Iron Age and Roman assemblages from Tiel-Passewaaijse Hogeweg, based on mandibular tooth eruption and wear (percentages out of the total number of aged mandibles).

decreases, and slaughter of adult cattle increases, most noticeably in phase 3 (fig. 5.21). Slaughter of younger cattle increases again in the Late Roman period. These data can be interpreted as a move from primarily meat production to an increased emphasis on products of the living animal, and then back

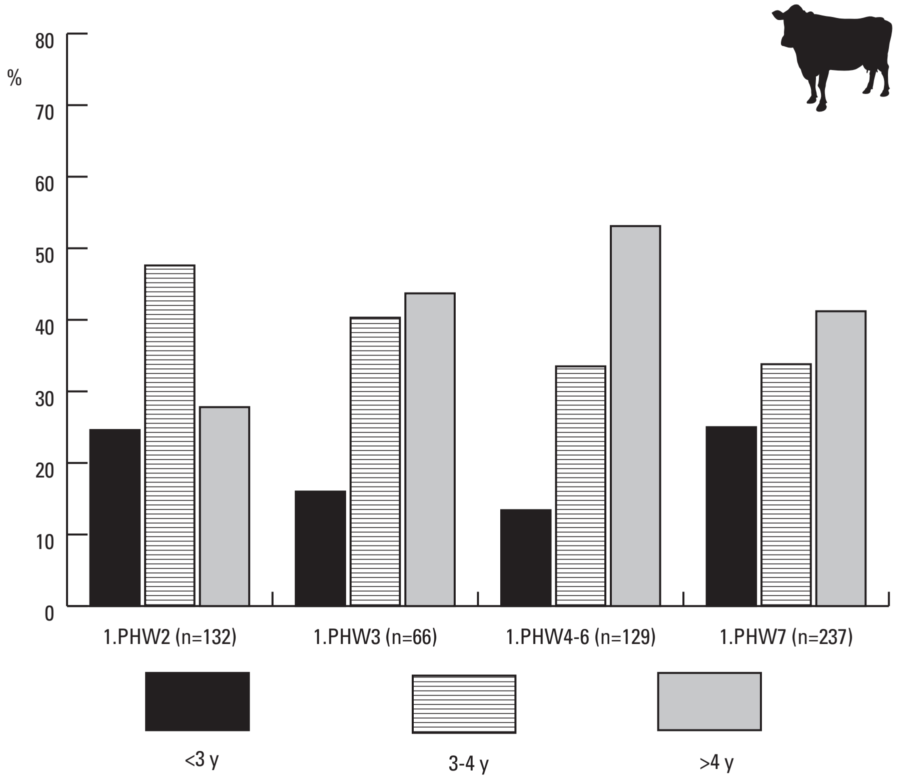

Fig. 5.21. Mortality profiles for cattle from all Roman assemblages from Tiel-Passewaaijse Hogeweg, based on epiphyseal fusion (percentages out of the total number of scored epiphyses per category). PHW2 overlaps with the Late Iron Age.

again to meat in the Late Roman period. Since there are no indications for milk production (in the form of calves younger than a year), labour and manure must have been the main products.

In Geldermalsen-Hondsgemet, there is also an increase in the proportion of cattle surviving to adulthood during the Roman period, but here the increase is more gradual than in Tiel-Passewaaijse Hogeweg (fig. 5.22). It already starts in the Late Iron Age/Early Roman period and continues into the Late Roman period. Epiphyseal fusion shows an increase in the proportion of adult cattle, but this does not occur until phase 4 (A.D. 150-270), and is preceded by a decrease from the Late Iron Age to phase 3 (fig. 5.23). The increase in adult slaughter continues in the Late Roman period.

5.4.3 SHEEP

5.4.3.1 Mandibular tooth eruption and wear

Combined data for the Early and Middle Roman period show high slaughter rates between 6 and 12 months (fig. 5.24). Data from the Late Iron Age/Early Roman period have been added to the Early Roman period to increase the data set. Seven of the nine assemblages show very high slaughter rates of sheep in the first two years of life (fig. E5.11). All these seven assemblages show peaks between 6 and 12 months. Two assemblages have lower rates of slaughter in the first two years: Geldermalsen-Hondsgemet 2 and Wijk bij Duurstede-De Horden. At Geldermalsen-Hondsgemet, a peak is found between 2 and 3 years, while slaughter at Wijk bij Duurstede-De Horden shows a peak between 3 and 4 years. For the six Middle Roman assemblages, slaughter rates in the first two years are also high: between 55 and 89 % (fig. E5.12). Again, most of these sheep are killed between 6 and 12 months. Not enough Late Roman data on mandibles were available for analysis.

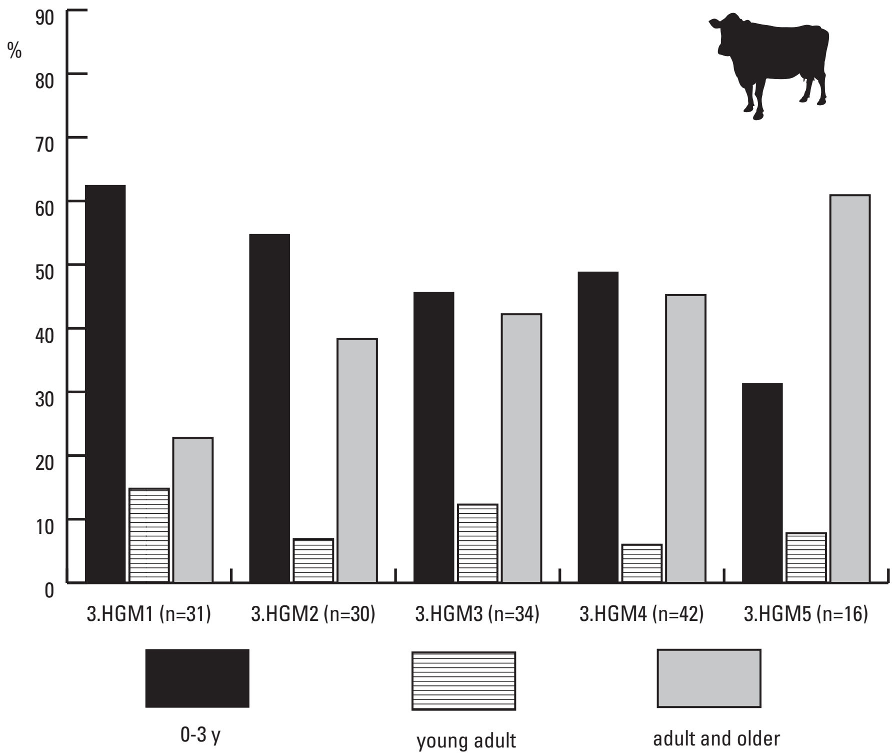

Fig. 5.22. Mortality profiles for cattle from Late Iron Age and Roman assemblages from Geldermalsen-Hondsgemet, based on mandibular tooth eruption and wear (percentages out of the total number of aged mandibles).

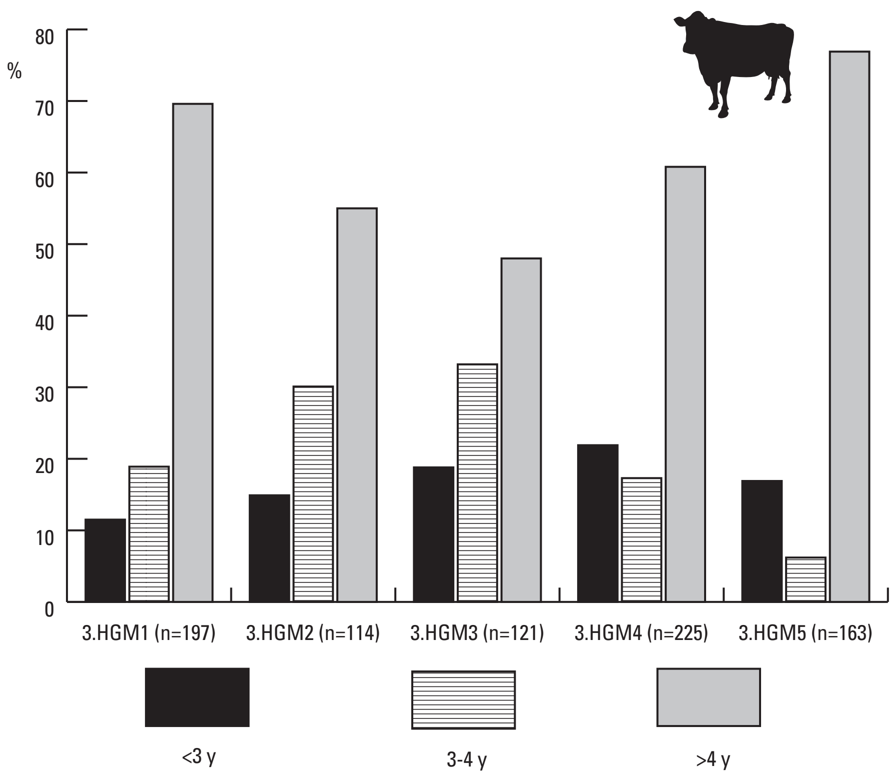

Fig. 5.23. Mortality profiles for cattle from Late Iron Age and Roman assemblages from Geldermalsen-Hondsgemet, based on epiphyseal fusion (percentages out of the total number of scored epiphyses per category).

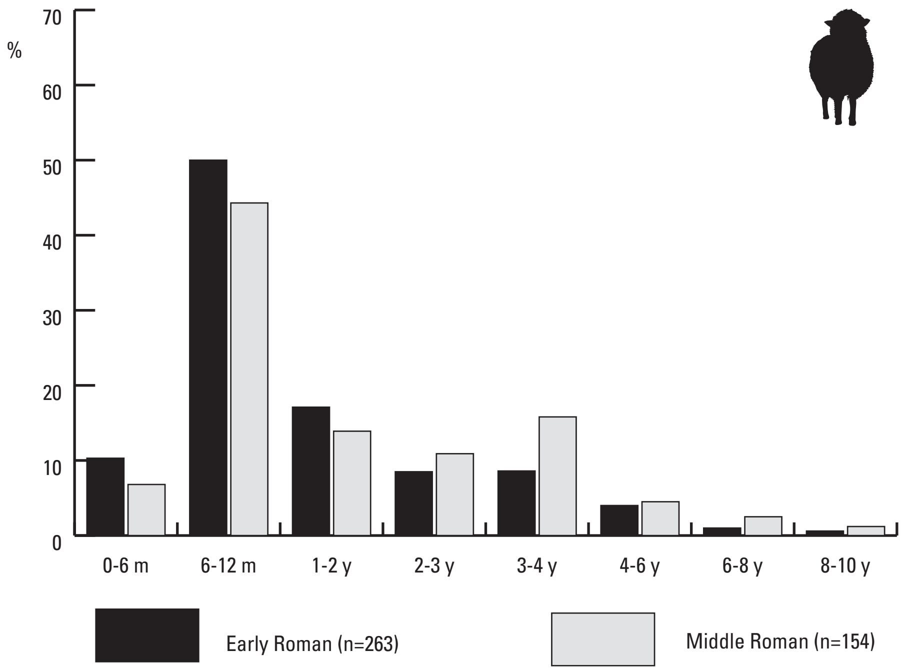

Fig. 5.24. Combined mortality profile for sheep/goat for nine assemblages from the Early Roman period and seven assemblages from the Middle Roman period, based on mandibular tooth eruption and wear (percentages out of the total number of aged mandibles).

5.4.3.2 Epiphyseal fusion

The proportion of unfused epiphyses for sheep was calculated for eight Early Roman assemblages. With a range from 12 to 68 %, the variability is high (fig. 5.25). The combined data for 12 assemblages give a proportion of unfused epiphyses of 47 % (n=554). The mortality profiles show very high slaughter rates in the first two years (21-40 % per year), and lower rates between 2 and 3.5 years (fig. E5.13).[493] The proportion of non-adult sheep in four Middle Roman assemblages ranges from 17 to 49 % (fig. 5.26). Combined data for 17 assemblages give a proportion of 30 % unfused epiphyses (n=392). Mortality profiles could only be calculated if broader age categories were used (fig. E5.14). Even then, the sample size for some sites or categories is smaller than the minimum used for cattle, and only three assemblages from two sites could be analysed. 15 to 40 % of sheep were killed between 0 and 2 years. Between 2 and 3.5 years, 9 to 54 % were killed. Survival into adulthood is especially low for the two assemblages from Tiel-Passewaaijse Hogeweg. Not enough data were available for the Late Roman period.

5.4.3.3 Developments within sites

We can follow developments in exploitation of sheep from the Late Iron Age or Early Roman period to the Middle Roman period in three different sites. Mandibular data for Tiel-Passewaaijse Hogeweg show a clear development from a strong emphasis on meat and milk (very high slaughter rates in the first year and few animals older than three years) in the Late Iron Age and Early Roman period up to A.D. 50 to more exploitation of wool (less slaughter in the first year and more animals older than

[493] Houten-Schalkwijkseweg does not reach the minimum of 75 epiphyses used elsewhere, but has been included because there are so few assemblages that could be used.

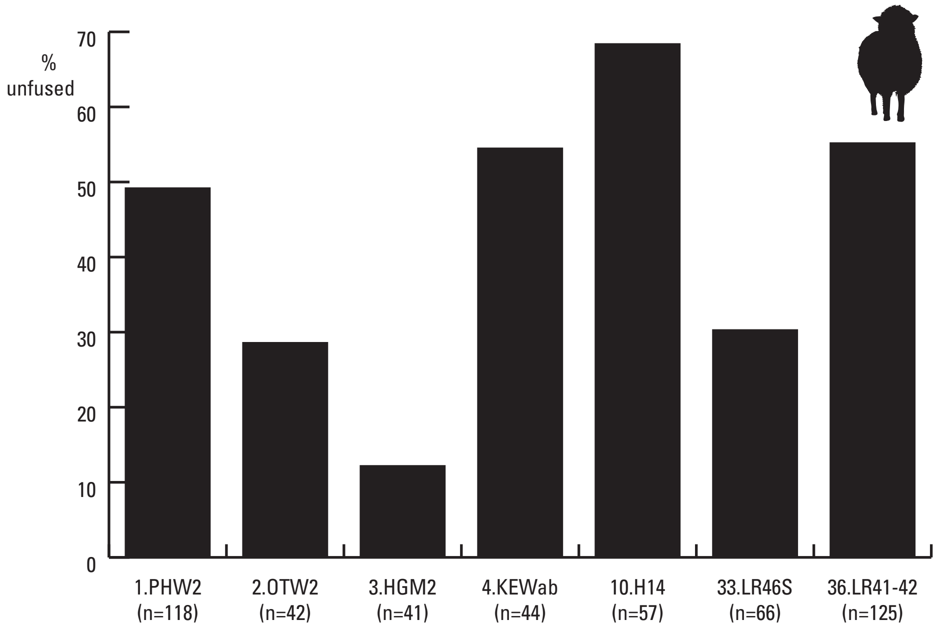

Fig. 5.25. Percentage of unfused epiphyses for sheep/goat from Early Roman assemblages (some with overlap with the Late Iron Age).

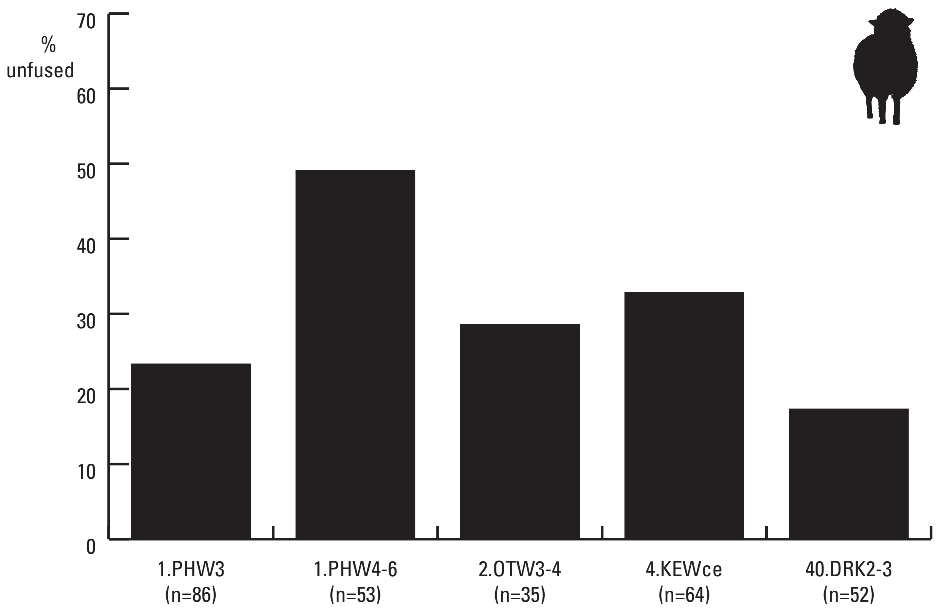

Fig. 5.26. Percentage of unfused epiphyses for sheep/goat from Middle Roman assemblages (PHW3 with overlap with the Early Roman period).

three years) in phase 3 (A.D. 50-140; fig. 5.27). The percentage of unfused epiphyses shows a decrease from phase 2 to phase 3, which means that more animals survived into adulthood in the later phase. This confirms the conclusion based on tooth wear.

The data for Geldermalsen-Hondsgemet are very different compared to the early phases in Tiel-Passewaaijse Hogeweg. Slaughter in the first year is much lower and survival beyond three years is

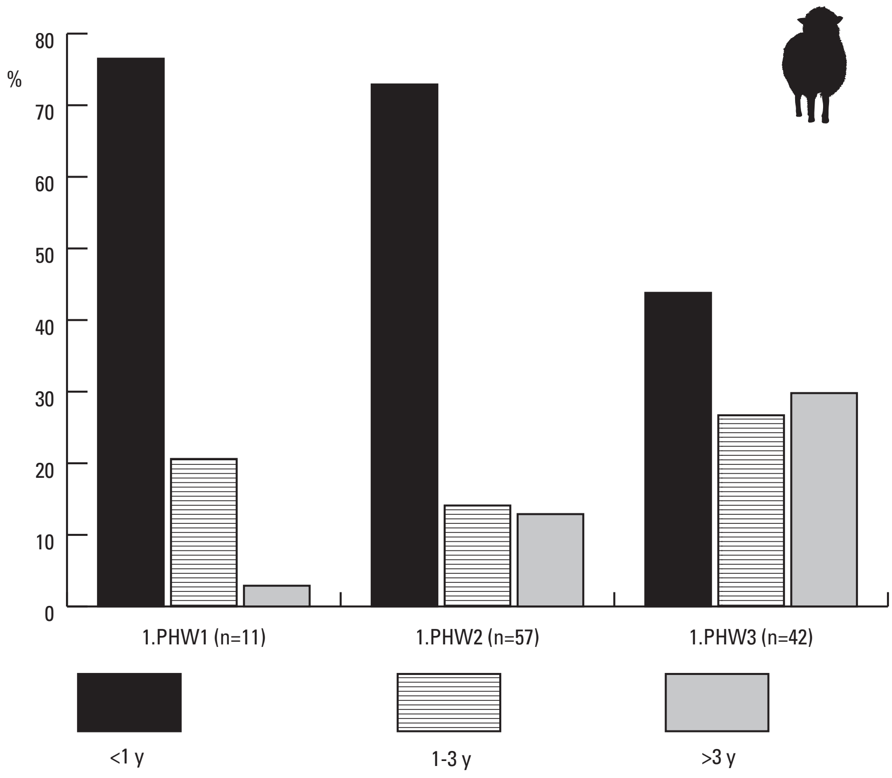

Fig. 5.27. Mortality profiles for sheep/goat from Late Iron Age and Roman assemblages from Tiel-Passewaaijse Hogeweg, based on mandibular tooth eruption and wear (percentages out of the total number of aged mandibles).

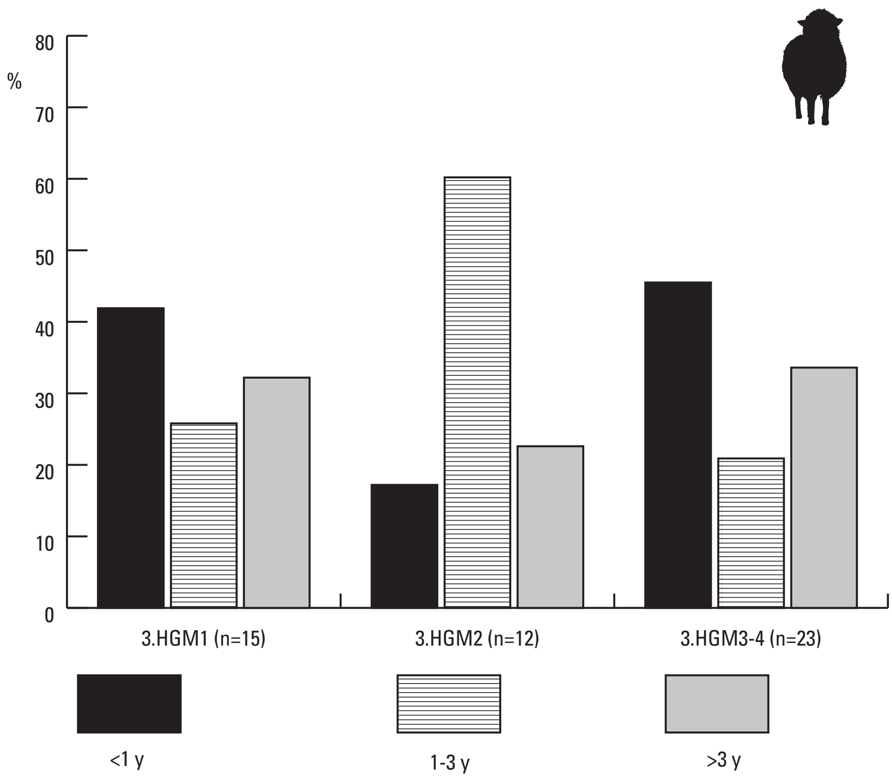

Fig. 5.28. Mortality profiles for sheep/goat from Late Iron Age and Roman assemblages from Geldermalsen-Hondsgemet, based on mandibular tooth eruption and wear (percentages out of the total number of aged mandibles).

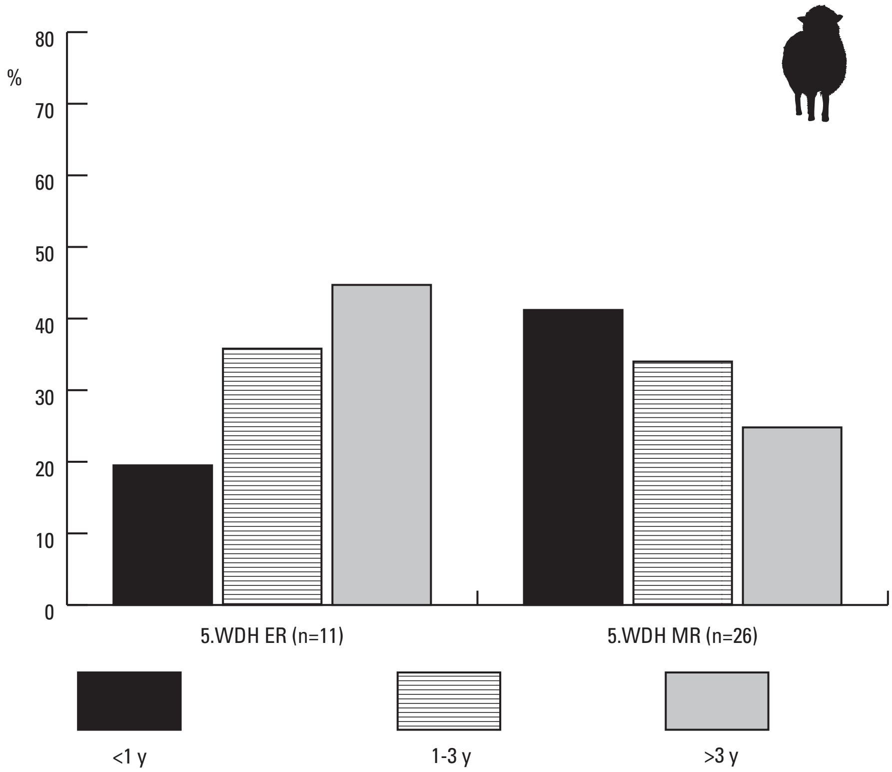

Fig. 5.29. Mortality profiles for sheep/goat from Late Iron Age and Roman assemblages from Wijk bij Duurstede-De Horden, based on mandibular tooth eruption and wear (percentages out of the total number of aged mandibles).

already relatively high in the Late Iron Age (fig. 5.28). In the Late Iron Age/Early Roman period (phase 2), there is a large slaughter peak between 1 and 3 years, which is not seen in the previous or later period. The mortality profile for phases 3 and 4 (A.D. 50-270, but most data are from phase 3) is very similar to that for the Late Iron Age. Wool was a more important product in the Late Iron Age than in Tiel-Passewaaijse Hogeweg, but declines somewhat in phase 2, when meat seems to have been the main product, although sheep were killed for meat at a later age than in Tiel-Passewaaijse Hogeweg. Phase 3-4 in Geldermalsen-Hondsgemet shows much similarity with phase 3 in Tiel-Passewaaijse Hogeweg, which indicates that exploitation of sheep was similar at this time: for wool and meat. Not enough epiphyseal fusion data were available for analysis.

Sheep exploitation in Wijk bij Duurstede-De Horden in the Early Roman period shows relatively little slaughter in the first year and good survival into adulthood (fig. 5.29). In the Middle Roman period, slaughter in the first year increases, while slaughter of adult sheep decreases. Nearly as much sheep were killed between 1 and 3 years as in the previous period. Exploitation seems to have focused on meat and wool, with an increased emphasis on meat in the Middle Roman period. Not enough epiphyseal fusion data were available for analysis.

5.4.4 HORSE

5.4.4.1 Tooth eruption and wear

The comparison between deciduous and permanent dentition for horses could only be made for two sites: Tiel-Passewaaijse Hogeweg and Geldermalsen-Hondsgemet. The results are interesting: for all three periods, the proportion of non-adult horses is much higher for Tiel-Passewaaijse Hogeweg (50-

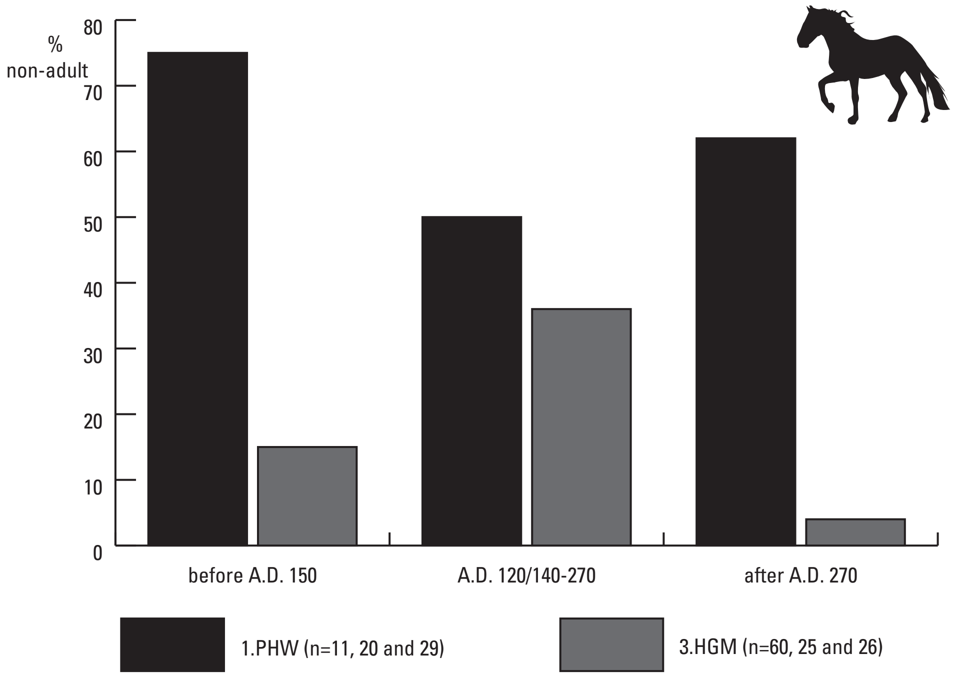

Fig. 5.30. The percentage of non-adult horses for Tiel-Passewaaijse Hogeweg and Geldermalsen-Hondsgemet, based on the eruption of maxillary and mandibular teeth.

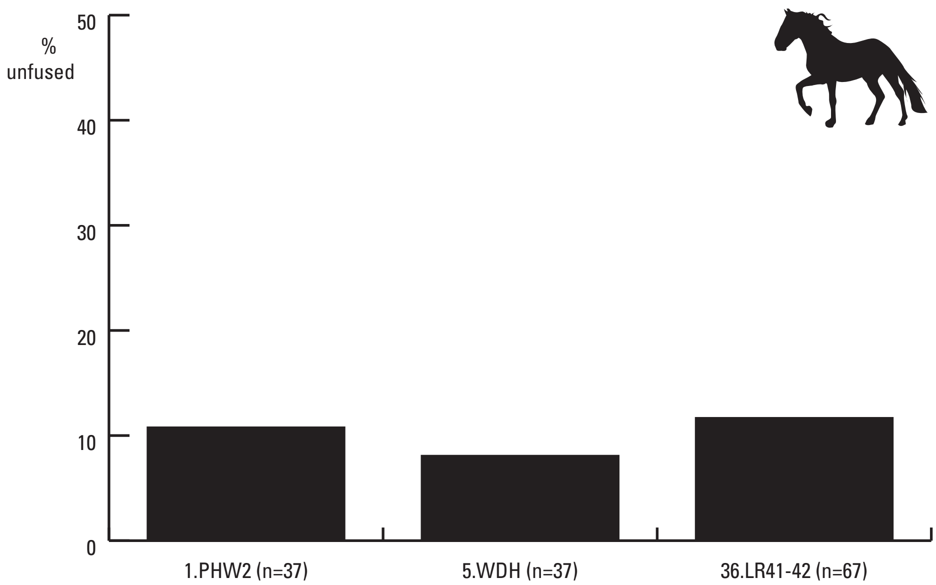

Fig. 5.31. Percentage of unfused epiphyses for horses from Early Roman assemblages (PHW2 with overlap with the Late Iron Age).

75 %) than for Geldermalsen-Hondsgemet (4-36 %; fig. 5.30). While the proportion of non-adults is lowest in Tiel-Passewaaijse Hogeweg between A.D. 150 and 270, this is when the proportion is at its highest in Geldermalsen-Hondsgemet. Mortality profiles based on crown height could only be calculated per period and not per site. Peaks occur in the category 5 to 10 years in most periods, except for the transitional Early/Middle Roman period, when more horses are killed between 10 and 15 years (fig. E5.15).

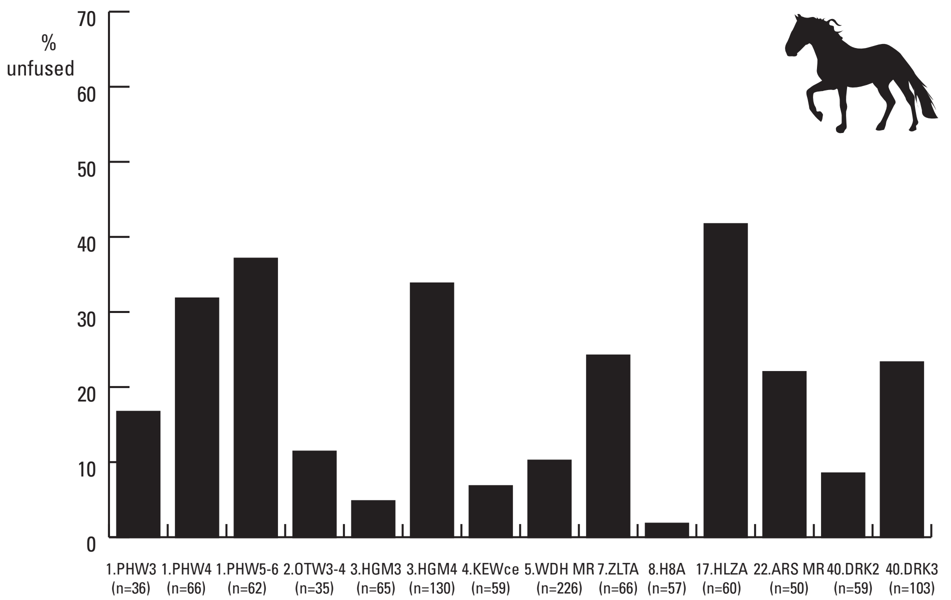

Fig. 5.32. Percentage of unfused epiphyses for horses from Middle Roman assemblages (some with overlap with the Early Roman period).

5.4.4.2 Epiphyseal fusion

The percentage of unfused epiphyses is low in all three Early Roman assemblages (fig. 5.31). The combined data for the Early Roman period give a similar result: 10 % unfused epiphyses (11 assemblages, n=281). Figure 5.32 shows the percentage of unfused epiphyses for horses in the Middle Roman period, which varies strongly. All four assemblages with a high percentage of unfused epiphyses show a high proportion (22-31 %) of horse in the species spectrum. Of the six assemblages with a low percentage of unfused epiphyses, four have a higher proportion of horse and two a low one. This suggests that there is no direct relationship between a large proportion of horse and high non-adult slaughter rates. The combined data for 23 Middle Roman assemblages give a proportion of unfused horse epiphyses of 20 % (n=1120). Figure E5.16 shows the mortality profiles for four Middle Roman assemblages. Relatively high slaughter rates in the second and third year are seen in Geldermalsen-Hondsgemet 4, but not in the other sites.

The percentage of unfused horse epiphyses could be calculated for only two Late Roman assemblages. For Geldermalsen-Hondsgemet 5, the proportion is 14 %, and for Tiel-Passewaaijse Hogeweg 7 it is 50 %. The combined data for five Late Roman sites give a proportion of unfused epiphyses of 36 % (n=235).

5.4.4.3 Developments within sites

Developments over time in the proportion of non-adult horses can be seen in Tiel-Passewaaijse Hogeweg and Geldermalsen-Hondsgemet, as has been described in 5.5.4.1. The proportion drops in Tiel-Passewaaijse Hogeweg after c. A.D. 150 and rises again in the Late Roman period (fig. 5.30). The opposite is visible in Geldermalsen-Hondsgemet, with an increase in non-adult horses after c. A.D. 150 and a decrease in the Late Roman period. Developments in mortality profiles based on epiphyseal fusion could be analysed for three sites, but only as a simple percentage of unfused epiphyses. The three sites (Tiel-Passewaaijse Hogeweg, Geldermalsen-Hondsgemet and Druten-Klepperhei) all show a significant increase in the percentage of unfused epiphyses (and thus the proportion of non-adult horses killed) around A.D. 150 (fig. 5.32).

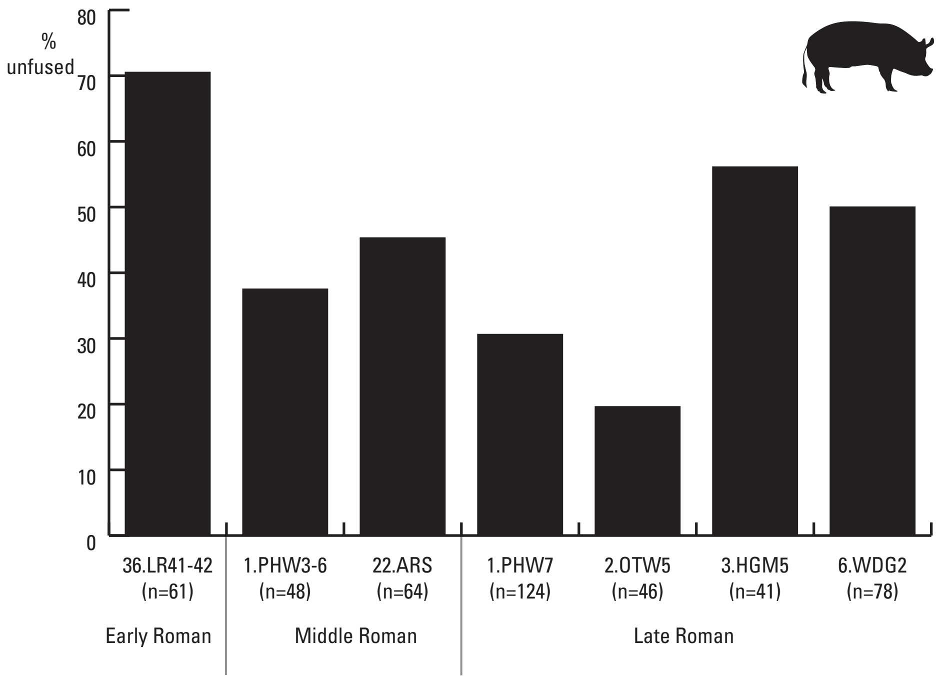

Fig. 5.33. Percentage of unfused epiphyses for pigs from Early, Middle and Late Roman assemblages.

5.4.5 PIG

5.4.5.1 Mandibular tooth eruption and wear

Mortality profiles for three Late Iron Age/Early Roman assemblages and combined data from six additional sites show a clear slaughter peak between 14 and 21 months (fig. E5.17). For the Middle Roman period, data sets were available for three sites, as well as a combined data set based on eleven other assemblages. Again, the highest slaughter peaks are found between 14 and 21 months (fig. E5.18). Analysis for the Late Roman period is also based on three sites. Again, clear slaughter peaks between 14 and 21 months occur at all three sites (50-61 %; fig. E5.19).

5.4.5.2 Epiphyseal fusion

The highest proportion (70.5 %) of unfused epiphyses is found in the only Early Roman assemblage (fig. 5.33). The combined data for the Early Roman period give a proportion of 63 % unfused epiphyses (8 assemblages, n=131). The combined data for 13 Middle Roman assemblages give a proportion of 46 % unfused epiphyses (n=186). The combined data for the Late Roman period give a proportion of 39.5 % unfused epiphyses (8 assemblages, n=357). A mortality profile could only be calculated for Late Roman Tiel-Passewaaijse Hogeweg. Few or no pigs were killed in their first year. Equal proportions of pigs were slaughtered between 1 and 2.5 years and between 2.5 and 3.5 years (29.4 and 29.6 %). 35 % lived into adulthood.

5.4.4.3 Developments within sites

Developments in mortality profiles based on mandibular tooth eruption and wear could be analysed for two sites, but only by combining phases. Tiel-Passewaaijse Hogeweg shows no development at all between the Late Iron Age/Early Roman period and Middle Roman period (fig. 5.34). More than 70 % of pigs are killed in the category 14-27 months. In the Late Roman period, this proportion is even higher. Mortality profiles for Geldermalsen-Hondsgemet show that in the Late Iron Age/Early

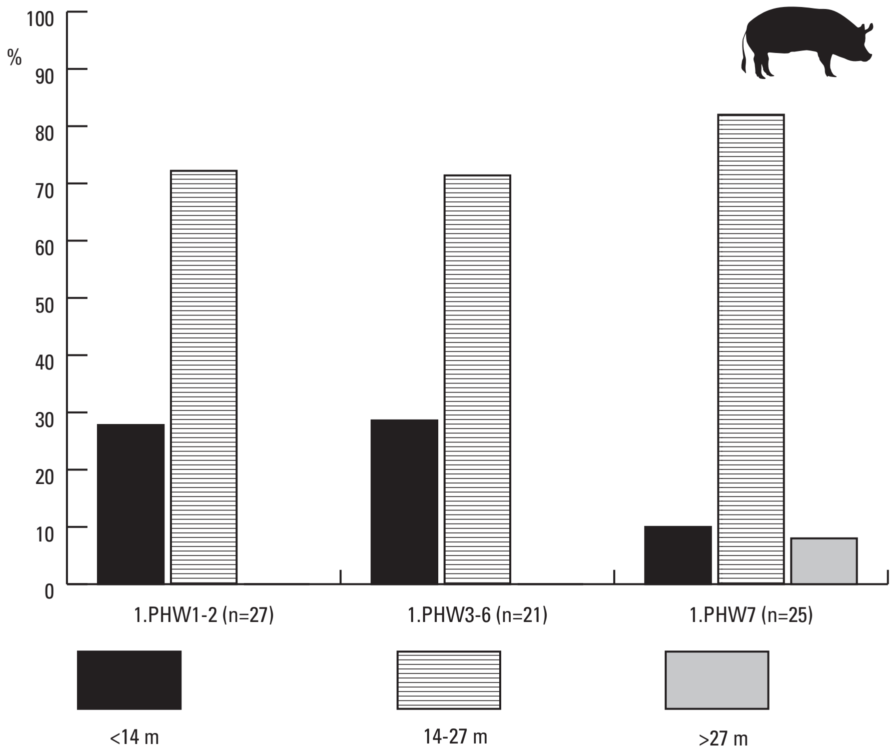

Fig. 5.34. Mortality profiles for pigs from Late Iron Age and Roman assemblages from Tiel-Passewaaijse Hogeweg, based on mandibular tooth eruption and wear (percentages out of the total number of aged mandibles).

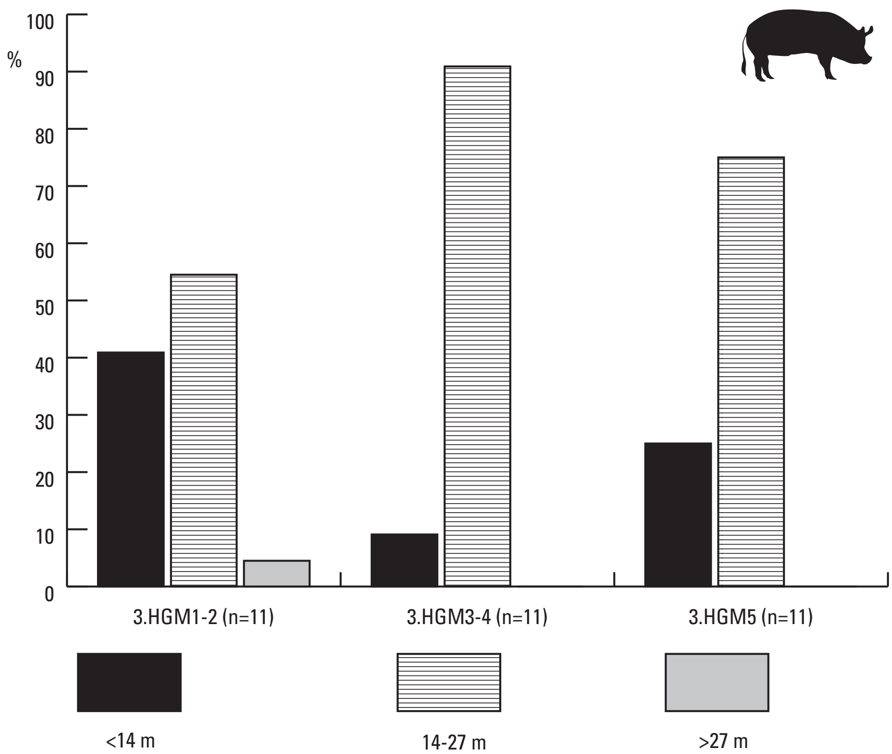

Fig. 5.35. Mortality profiles for pigs from Late Iron Age and Roman assemblages from Geldermalsen-Hondsgemet, based on mandibular tooth eruption and wear (percentages out of the total number of aged mandibles).

Roman period, pigs were mainly slaughtered in two age categories: younger than 14 months and 14-27 months (fig. 5.35). The Middle Roman period shows an increase in slaughter in the category 14-27 months. Epiphyseal fusion data were even scarcer. Only for Tiel-Passewaaijse Hogeweg could different phases be compared, but only for the Middle Roman (after c. A.D. 150) and Late Roman periods and only as a percentage of unfused epiphyses. The proportion of non-adult pigs remains roughly similar between these periods at just over 30 % (fig. 5.33).

5.5 Skeletal element distribution

5.5.1 Representation of body parts

The proportions for five different categories were calculated for individual assemblages, and grouped into the Late Iron Age/Early Roman period, Early Roman period, Middle Roman period and Late Roman period.[494] In total, 37 assemblages could be included. These assemblages come from 22 of the 45 rural sites included in this study, and two Iron Age sites: Bunnik and Lith.[495] Data from these two Iron Age sites were used to provide a baseline for a subsistence society.

Since cattle hides and brawn are the most commonly mentioned animal products for our region,[496] the focus here is on phalanges (moved with the hide) and fragments from the head (waste from making brawn). If cattle hides were indeed a product of rural settlements in the Roman period, then we would expect to find a decrease in the proportion of phalanges from the Late Iron Age to the Roman period. A market for hides and meat products first arose in the Early Roman period with the establishment of the *limes* and the town of Nijmegen, but it may have taken some time for local production systems and supply networks to become established. The lowest proportions should therefore be found in the Middle Roman period, when surplus production should be established. For the production of brawn, the proportion of the category 'head+neck' should increase during the Roman period.

Skeletal element distribution was analysed for five assemblages from the Late Iron Age (fig. E5.20). Proportions of phalanges vary between 5 and 10 %, and proportions of head+neck from 21 to 38 %. These figures should be seen as normal for sites where there is no production for an external market. Eight assemblages from the Late Iron Age/Early Roman period could be included in this analysis (fig. E5.21). The proportion of phalanges ranges from 4 to 14 %. The proportion for head and neck fragments varies from 17 to 46 %.

Another seven assemblages date to the Early Roman period and the early part of the Middle Roman period (all before A.D. 150). The proportion of phalanges ranges from 4 to 16 % (fig. E5.22). Five assemblages have proportions of 10 % or higher. The proportion of head+neck varies from 25 to 36 %. For the Middle Roman period, 13 assemblages from 12 sites were analysed (fig. E5.23). The proportion of phalanges varies between 1 and 9 %, with six assemblages showing proportions lower than 5 %. For head+neck, proportions range from 22 to 38 %. Of the three sites for which a development over time could be studied, Tiel-Passewaaijse Hogeweg and Tiel-Oude Tielseweg both show a decrease in the proportion of phalanges around c. A.D. 150 (from 14 to 7 % in Tiel-Passewaaijse Hogeweg from phase 3 to 4; and from 16 to 7 % in Tiel-Oude Tielseweg from phase 3 to 4). For the four assemblages from the Late Roman period, the proportion of phalanges ranges from 2 to 15.5 % (fig. E5.24). The proportion of head+neck fragments varies between 21 and 48 %.

494 As explained in paragraph 4.4, it may have been preferable to use total weight per skeletal element category to avoid differential fragmentation; however, these data were unavailable for most sites.

495 Groot in press a; Roymans s.a.

496 See paragraph 3.3.

When the proportions for the five categories for the archaeological data are compared with those for a complete cattle skeleton (fig. 4.1), the underrepresentation of phalanges and overrepresentation of head+neck fragments is clear. However, this is found for all sites, including those dating to the Iron Age. This makes it more likely that this distribution is a general pattern caused by taphonomical processes and biases of recovery. Taphonomy must have been a major factor, but it is difficult to estimate to what extent. No relation can be found between a high or low taphonomical index or index of representativeness and high or low proportions of phalanges (see table E5.2). Either the approach taken here in analysing taphonomical factors is not enough to explain differences in skeletal element distribution, or other factors play a larger role.

Comparing skeletal element distribution for cattle and horses – animals of a similar size, but which were probably treated in different ways – can help us to further understand the data. The proportion of horse phalanges for five assemblages from the Late Iron Age/Early Roman period ranges from 7 to 16 % (fig. E5.25). Three assemblages from the later Early and early Middle Roman period have similar proportions of phalanges, between 11.5 and 13 % (fig. E5.26). For the Middle Roman period, data from 11 assemblages are included; the percentage of phalanges ranges from 3 to 16 % (fig. E5.27). Two assemblages from the Late Roman period have proportions of phalanges between 4 and 8 % (fig. E5.28). Overall, the proportion of phalanges seems to be slightly higher for horse than for cattle.

The comparison with horse suggests a slight underrepresentation of cattle phalanges. Furthermore, although the proportion of cattle phalanges is variable in all periods, it is interesting that no high proportions were found for the Middle Roman period. Although other factors such as taphonomy and excavation strategy probably had a large affect on skeletal element distribution, this does not become clear when the results from the taphonomical study are included. Therefore, the movement of hides could have played a contributing role. However, this can never have occurred at a large scale. First of all, the phalanges do not show a clear pattern, and second, there is no evidence for any systematic slaughter of cattle or preservation of meat. Beef cattle would have been transported to the markets alive. If hides were indeed one of the surplus products of rural settlements in the Dutch River Area, then this must have been limited to the hides of cattle that were slaughtered for local consumption.

Very little development can be seen for the head+neck proportion. This category is slightly lower in the Late Roman period. A lack in clear developments over time makes it hard to confirm the brawn hypothesis. A more detailed analysis at site level may be able to find evidence for brawn, for instance when large numbers of head fragments are found in a certain part of a site. However, it should be remembered that cattle skulls are usually found fragmented and can then consist of hundreds of fragments.[497]

5.5.2 MEAT-BEARING VERSUS NONMEAT-BEARING LIMB BONES

For cattle, data were available for 29 assemblages from 17 sites.[498] The proportions of meat-bearing and nonmeat-bearing bones show a lot of variety, with the proportion of meat-bearing bones varying between 42.5 and 88 % (fig. E5.29). The only trend that the data seem to show is an increase in the proportion of meat-bearing bones in the Late Roman period.

Although data for sheep/goat could be analysed for a much smaller number of assemblages, they show the same variety found for cattle, with the proportion of meat-bearing bones varying between 33 and 76 % (fig. E5.30).[499] Tiel-Passewaaijse Hogeweg stands out from the other sites with a very low proportion of meat-bearing bones.

497 This is why weight would be more suitable for skeletal element analysis, but data were only available for few assemblages.

498 This includes the Late Iron Age site of Lith, which was also included in paragraph 5.5.1.

499 Again, including the Late Iron Age site of Lith.

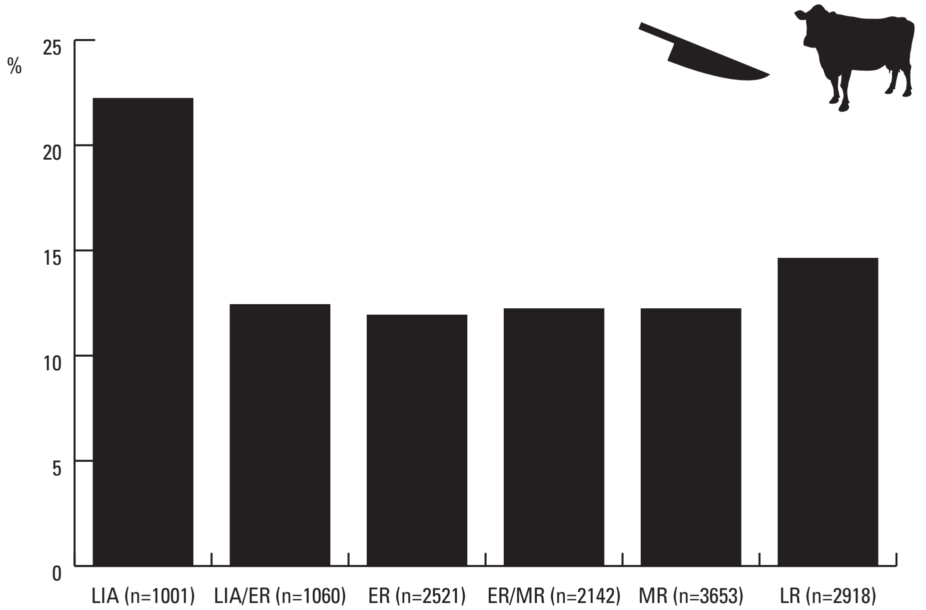

Fig. 5.36. Percentage of butchery marks for cattle per period (out of the total number of fragments).

Very few assemblages contained enough pig fragments to allow analysis of the limb bones. Three assemblages from three sites could be included, two of which date to the Late Roman period. The assemblage Tiel-Oude Tielseweg 5 is interesting, because it shows a dominance of meat-bearing bones (97 %). However, most of the bones were collected from just one large pit, and this assemblage is therefore not representative. The proportion of meat-bearing bones in the other two assemblages is 75 % (Arnhem-Schuytgraaf, mainly Middle Roman) and 80 % (Tiel-Passewaaijse Hogeweg, Late Roman).

5.6 Butchery

5.6.1 Cattle

In the study of butchery marks, the lack of good data turned out to be a major problem. Not all reports include quantifiable or primary data on butchery, and many reports do not differentiate between cut and chop marks. To carry out a detailed analysis of butchery, even more information is needed, and that kind of information was very limited. Furthermore, there are few sites with a long occupation, a good chronology and large samples, which offer the best chance of studying developments over time. Nevertheless, an attempt was made to see if any new insights could be reached by analysing butchery marks in Roman rural sites.

The percentage of butchery marks on cattle bones varies from 1 to 37 % (for 42 assemblages with more than 50 cattle fragments). When the percentage of butchery marks is looked at per period, it is just as variable. The total percentage of butchery marks per period shows a marked decrease in the Early Roman period, and then remains stable until the Late Roman period, when a small increase is observed (fig. 5.36).

The total ratio of chop marks to cut marks per period shows an increase during the Roman period that starts in the Early Roman period and continues until the Late Roman period (fig. 5.37). The ratios for individual sites show a lot of variation between sites, but the highest ratios are found in the Middle and Late Roman periods (fig. 5.38). Development in chop-cut ratios within sites could only be studied

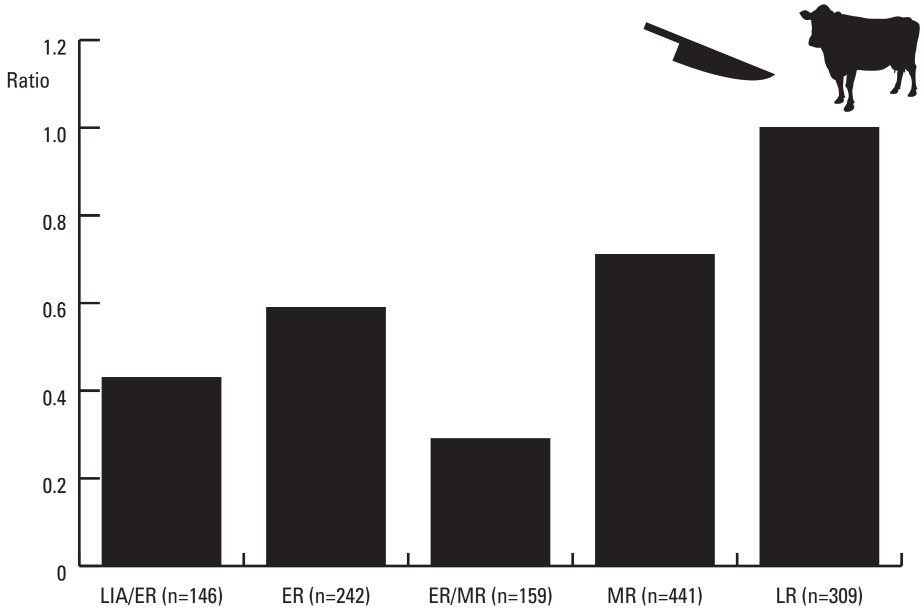

Fig. 5.37. Chop-cut index (ratio of chop to cut marks) for cattle per period (n is the number of butchery marks and not the number of fragments).

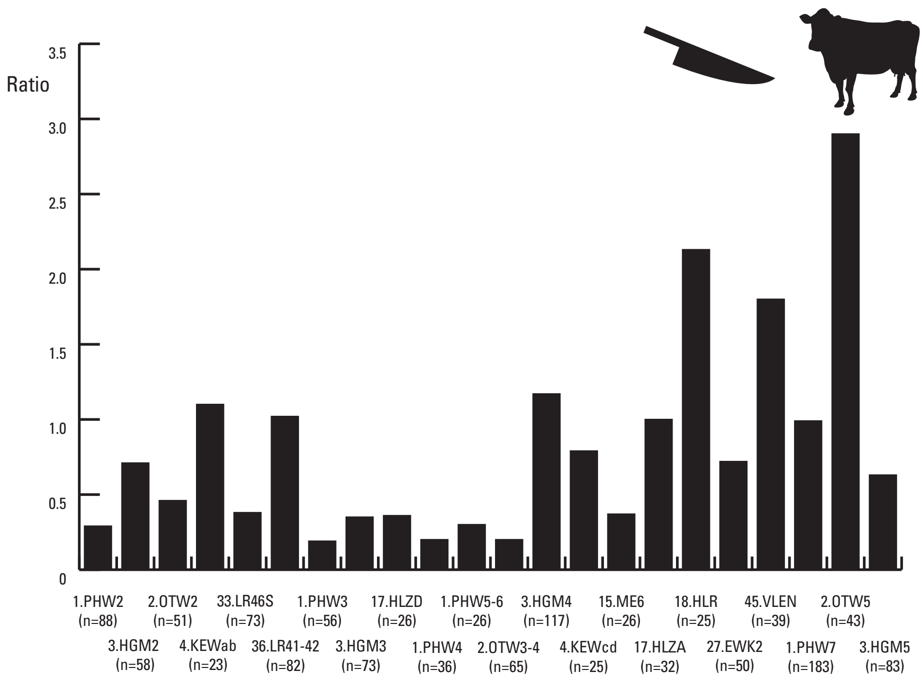

Fig. 5.38. Chop-cut index for cattle per site (n is the number of butchery marks and not the number of fragments).

for three sites. In Geldermalsen-Hondsgemet, the ratio fluctuates: it increases in the Late Iron Age/ Early Roman period (phase 2), decreases in phase 3, and then increases again, more strongly, around A.D. 140 (fig. 5.39). A decrease is noticed again in the Late Roman period. In Tiel-Passewaaijse Hogeweg and Tiel-Oude Tielseweg, no significant changes occur until the Late Roman period, when the ratio increases strongly (figs 5.40 and 5.41).

The proportions of chopped-through marks and superficial chop marks do not show a clear pattern (fig. 5.42). Unfortunately, only a few assemblages could be analysed in this way, and some of

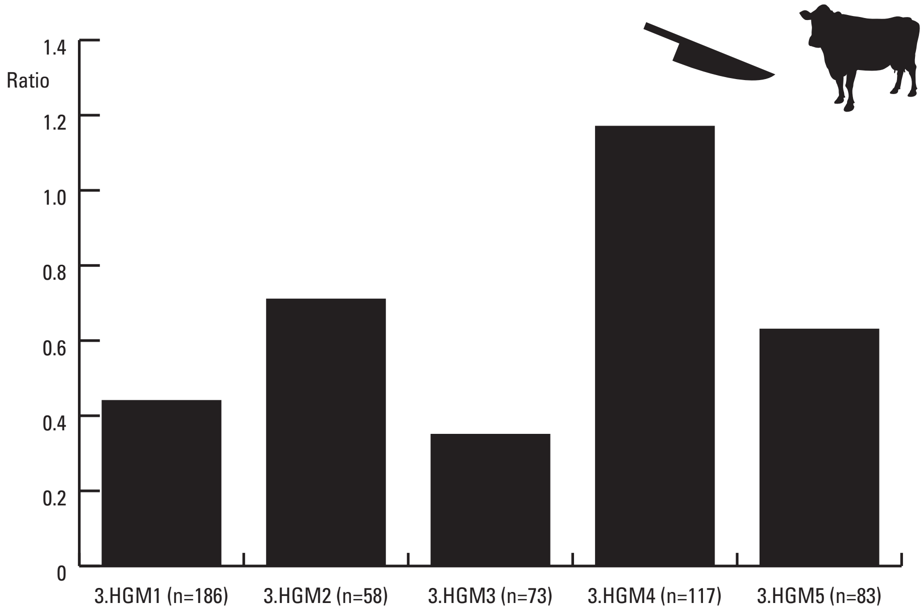

Fig. 5.39. Chop-cut index for cattle for Geldermalsen-Hondsgemet per period (n is the number of butchery marks and not the number of fragments).

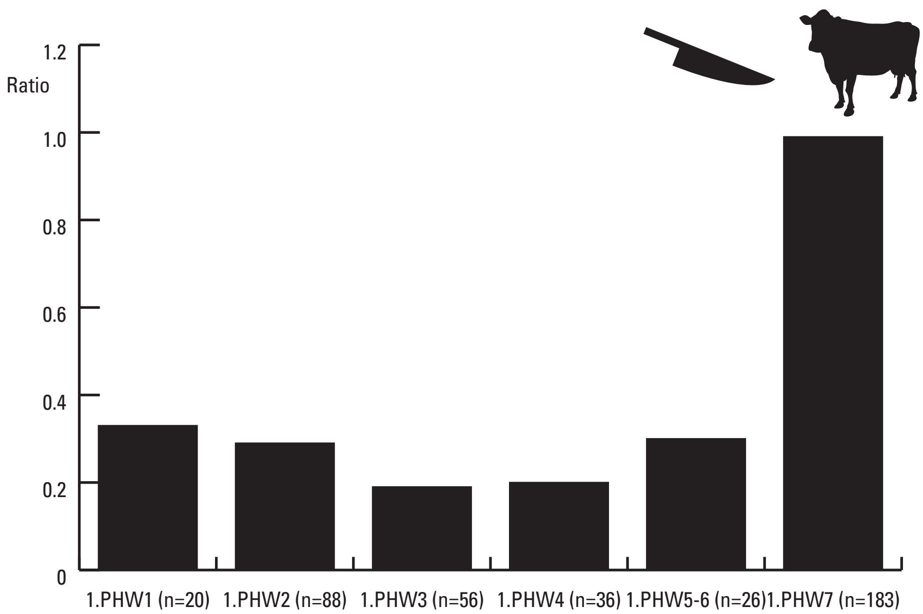

Fig. 5.40. Chop-cut index for cattle for Tiel-Passewaaijse Hogeweg per period (n is the number of butchery marks and not the number of fragments).

the samples are small. Geldermalsen-Hondsgemet has the highest proportion of chopped-through marks in the period A.D. 140-270, which is also when the chop to cut mark ratio is at its highest. Butchery methods in this period clearly differed from those in earlier and later periods. For the other sites, Utrecht-LR41-42 is striking because this Early Roman assemblage has a high proportion of chopped-through marks. Two of the three Late Roman assemblages also have rather high proportions of chopped-through marks.

Data from Geldermalsen-Hondsgemet can demonstrate how cattle were butchered. Phases 3 and 4 (Middle Roman period) have been combined to acquire a representative data set for the Roman period

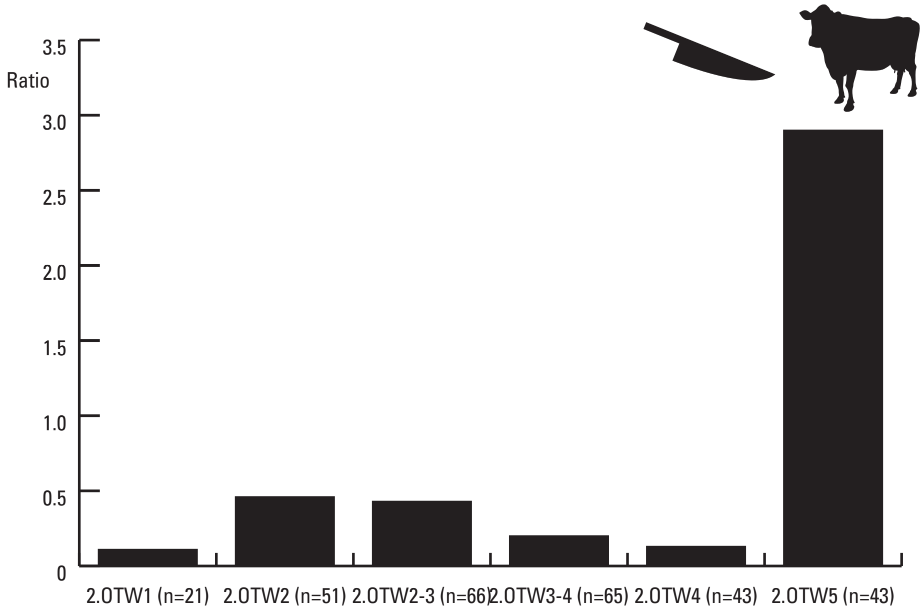

Fig. 5.41. Chop-cut index for cattle for Tiel-Oude Tielseweg per period (n is the number of butchery marks and not the number of fragments).

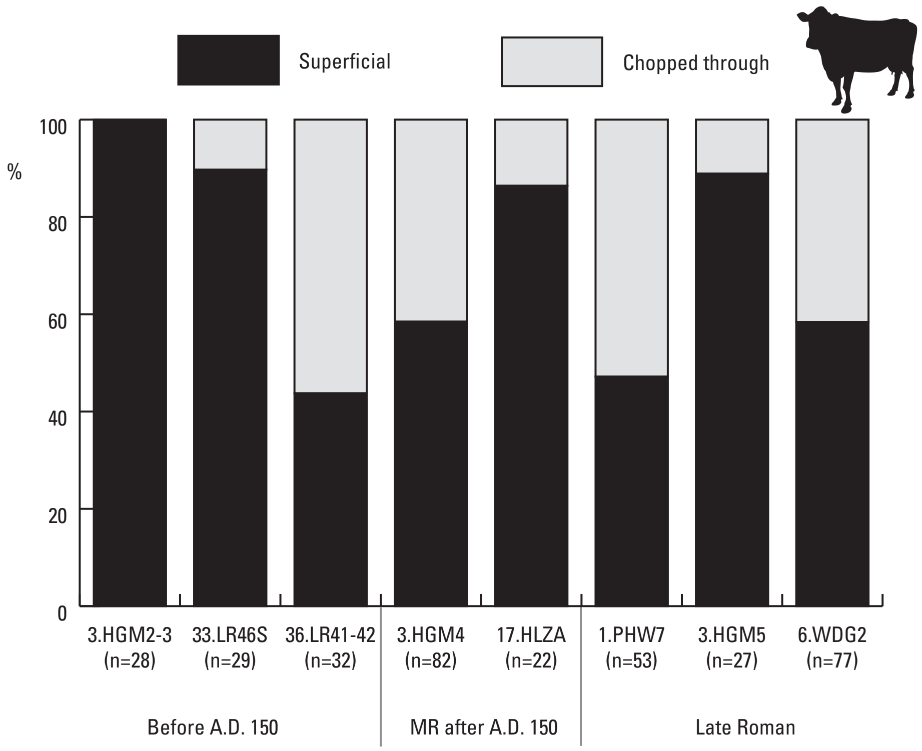

Fig. 5.42. Ratios of chopped-through and superficial chop marks on cattle bones per site (n is the number of butchery marks and not the number of fragments).

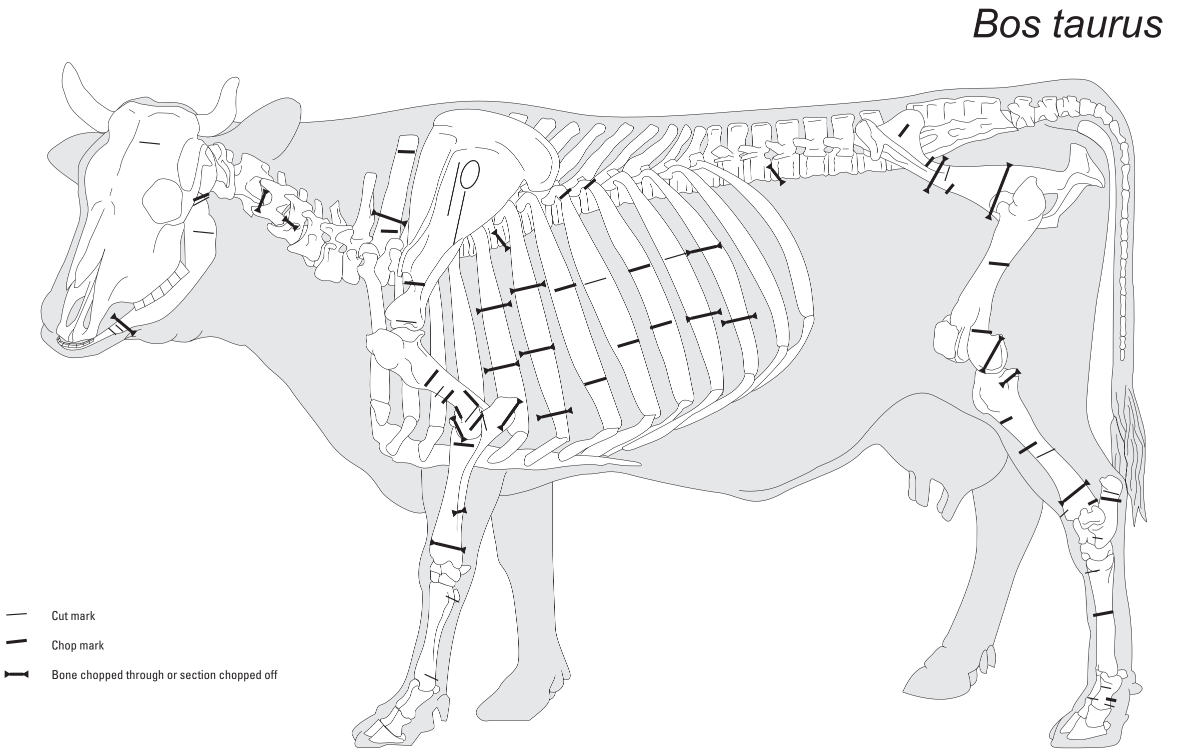

Fig. 5.43. Butchery marks on cattle bones from Geldermalsen-Hondsgemet 3-4 (A.D. 40-270) (Template: archeozoo.org).

(with a total of 230 butchery marks recorded; fig. 5.43). Cut marks on the atlas (the first vertebra of the neck) seem to be related to the removal of the head from the spinal column.[500] Butchery marks on the mandible can be a result of the separation of the mandible from the skull, and the removal of the ox cheek, which constitutes most of the meat on the head.[501] Chop marks on the vertebrae are likely to be a result of the segmentation of the spinal column into smaller fragments or the removal of the meat from the spine. The ribs were removed from the spinal column, chopped into smaller sections, and then the meat was removed. A perforation in the blade was present in two shoulderblades; this perforation occurs when the shoulder is hung for smoking (fig. 5.44).[502] The pelvis has been chopped through in several cases, separating the hind limb from the rump.[503] Cut marks on the metatarsal can be related to removing the lower limb,[504] or skinning when the lower limbs were left attached to the skin. Cut marks on the phalanges also occurred during skinning.[505]

500 Peters 1998, 260.

501 Maltby 1989, 78; 2010, 128-129; Rixson 1989, 56.

502 Schmid 1972, 42-43. Perforated cattle shoulderblades have also been found in Utrecht-LR46S and Utrecht-Wachttoren Gemeentewerf.

503 Maltby 2010, 129.

504 Maltby 2010, 139; 1989, 86.

505 Maltby 2010, 140.

Fig. 5.44. Perforated cattle shoulderblade from Geldermalsen-Hondsgemet.

5.6.2 HORSE

The percentage of butchery marks on horse bones varies from 0 to 21 % (29 assemblages with more than 50 horse fragments). The total percentage of butchery marks per period is always lower compared to that for cattle. Like cattle, there is a decrease in butchery in the Early Roman period, but it is not as large as that for cattle (fig. 5.45). This slight decrease continues in the Middle and Late Roman period.

The ratio of chop to cut marks could only be calculated for three assemblages: Tiel-Oude Tielseweg 2-3, Geldermalsen-Hondsgemet 4 and Tiel-Passewaaijse Hogeweg 7. These assemblages are from different sites, but from successive phases. The ratio is highest for Geldermalsen-Hondsgemet 4 (fig. 5.46). The proportions of chopped-through and superficial chop marks could only be established for Geldermalsen-Hondsgemet 3-4, where the superficial chop marks are much more common (18 versus 3 chopped-through marks).

The butchery marks on horse bones from Geldermalsen-Hondsgemet phases 3 and 4 give insight into the processing of horse carcasses (fig. 5.47). Chop marks through the ribs can be explained by cutting the ribs into portions that would fit into a cooking vessel. The shoulderblade shows butchery marks around the articulation, probably a result of disarticulating the forelimb, as well as cut and chop marks that are usually interpreted as occurring during meat removal. Butchery marks on the long bones suggest dismemberment and removal of meat. Cut marks on the metapodials and phalanges are probably a result of skinning. Overall, the butchery marks indicate that horses were skinned, disarticulated, cut into smaller portions, and had the meat removed from the bones. The cut marks on the shoulderblade are also frequently found on cattle shoulderblades, and then interpreted as indicating smoked shoulders.[506] The data clearly suggest that horse meat was consumed.

[506] Lauwerier 1988, 156; Maltby 2010, 287; Peters 1998, 260; Van Mensch/IJzereef 1977. The cut marks are often seen together with trimming of the articular end, removal of the spine, and a perforation in the blade from the hook on which the shoulder was suspended for smoking. Schmid 1972, 42-43.

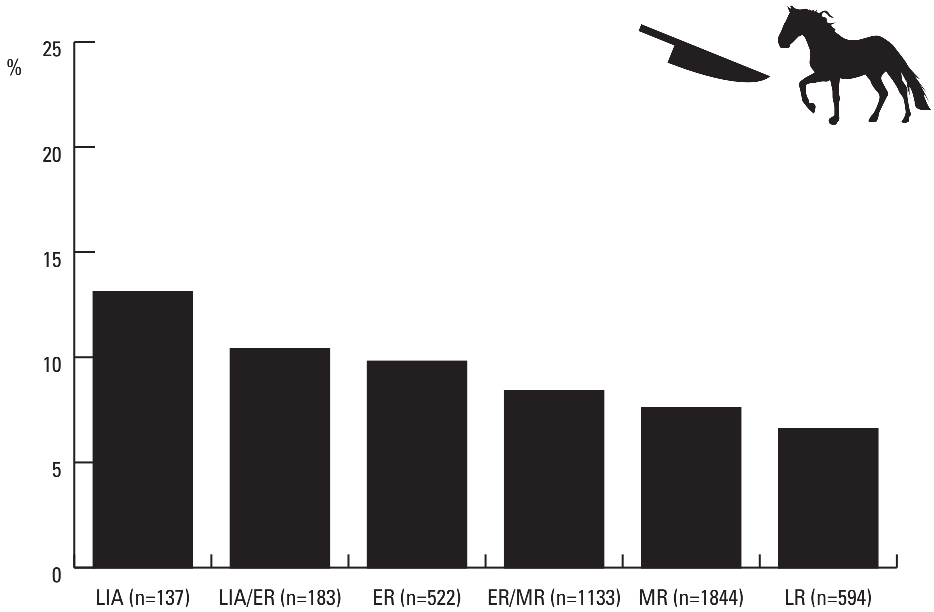

Fig. 5.45. Percentage of butchery marks for horse per period (out of the total number of fragments).

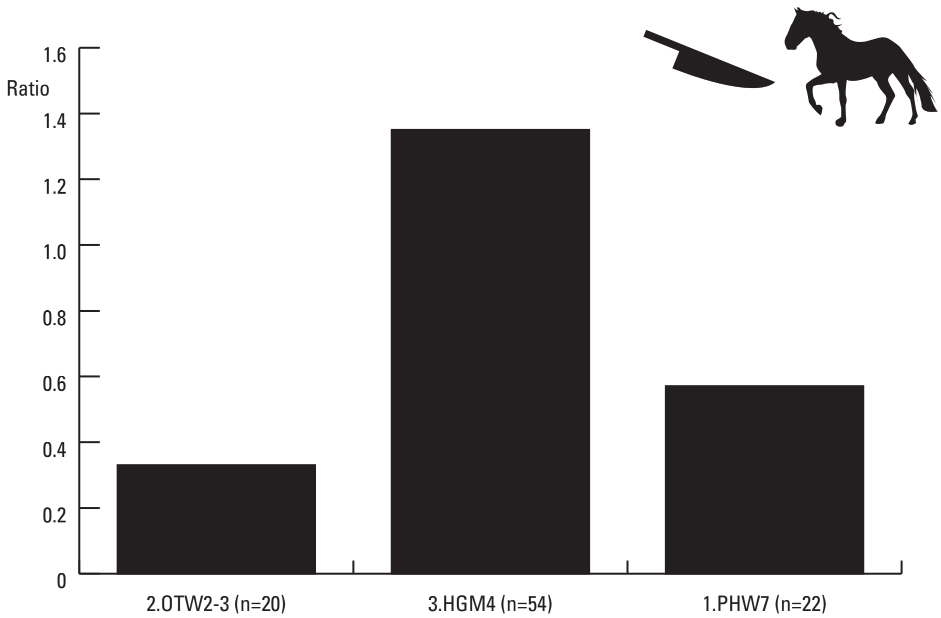

Fig. 5.46. Chop-cut index for horse per site (n is the number of butchery marks and not the number of fragments).

Butchery marks that are indicative of food preparation (e.g. chopping ribs into smaller sections) or meat removal (cut or superficial chop marks on the shafts of meat-bearing limb bones) have also been found in Tiel-Passewaaijse Hogeweg, Utrecht-LR46S, Huissen-Loostraat Zuid sites A and D, Utrecht-LR60 and Utrecht-Wachttoren Gemeentewerf.[507]

[507] Groot 2008a, 80; 2008c; 2010b; Meijer 2011, 111; Esser 2013.

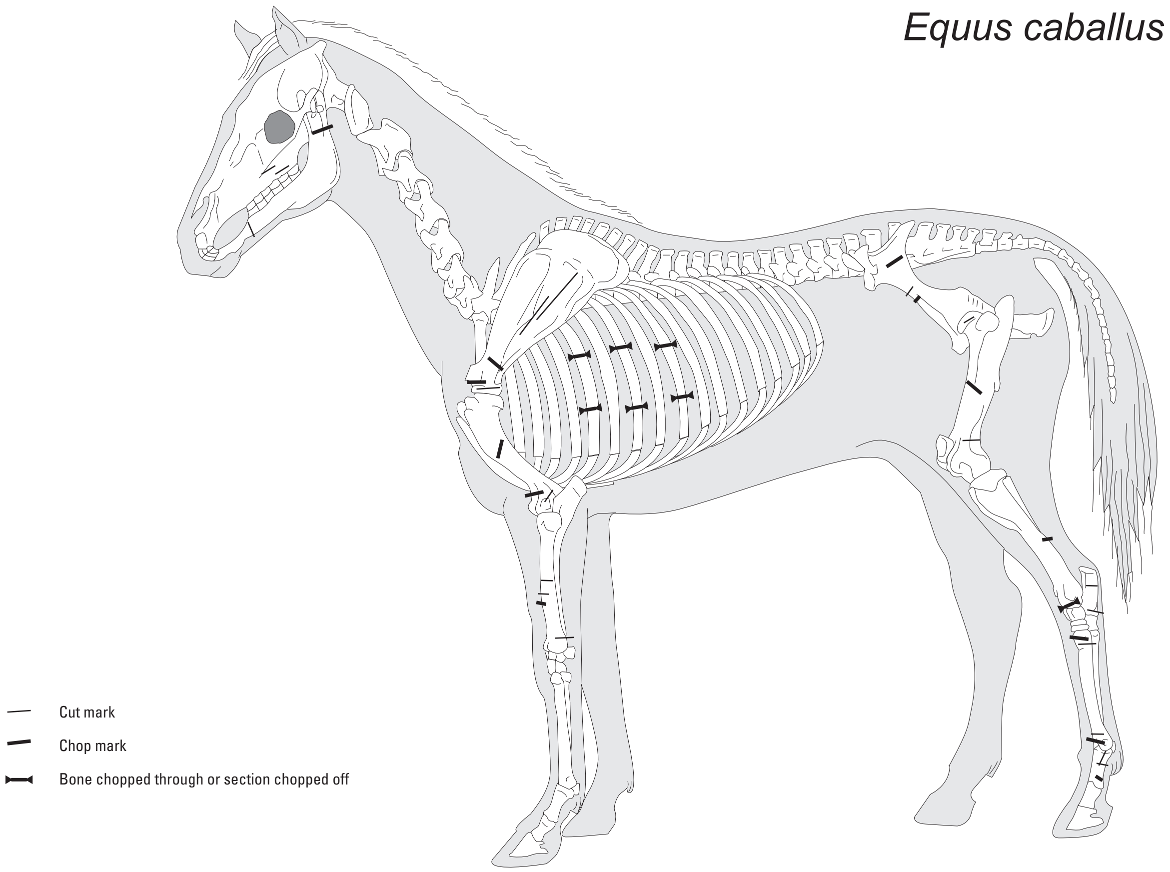

Fig. 5.47. Butchery marks on horse bones from Geldermalsen-Hondsgemet 3-4 (A.D. 40-270) (Template: archeozoo.org).

There seems to be no doubt that horse meat was consumed in rural sites; how common this was is more difficult to establish. The presence of articulated remains or complete skeletons is mentioned as an argument against consumption of horse meat.[508] However, in some cases the skeletons are part of ritual deposits. Moreover, complete skeletons of cattle, sheep and pig are also found.[509] A comparison of the fragmentation of horse and cattle bones is more informative. In some sites fragmentation of horse and cattle bones is similar (e.g. Utrecht-Wachttoren Gemeentewerf, Tiel-Passewaaijse Hogeweg phases 2-4 and Huissen-Loostraat Zuid site D), while in others horse bones are slightly or significantly less fragmented (e.g. Tiel-Passewaaijse Hogeweg phases 1, 5-6 and 7, Geldermalsen-Hondsgemet, Utrecht-LR46 and Utrecht-LR60). Lauwerier mentions lower fragmentation and a lower percentage of butchery marks compared to cattle as arguments against the consumption of horse meat in a number of rural sites, including Wijk bij Duurstede-De Horden and Ewijk-De Woerdjes.[510]

Butchery marks on horse bones have been explained by segmentation of carcasses to feed dogs.[511] Therefore, differences in gnawing marks between horse and cattle bones are of interest. The percentages of gnawing marks on horse and cattle bones could be compared for 32 assemblages (table E5.21). The percentage of gnawing marks on horse bones is higher than that on cattle bones in 16 cases; in the other cases, it is lower or equal. This does not seem convincing proof that horses were only butchered to provide meat for dogs.

[508] Lauwerier 1999, 107.

[509] Groot 2008a; 2009a.

[510] Lauwerier 1999, 108.

[511] Laarman 1996a, 356.

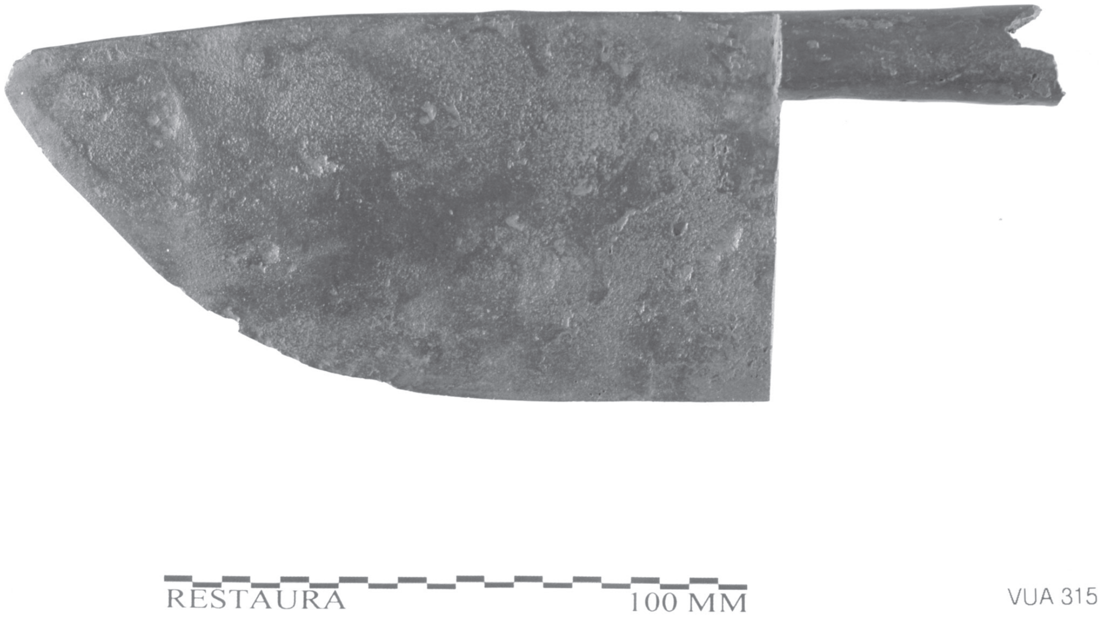

Fig. 5.48A. Cleaver from Geldermalsen-Hondsgemet (Van Renswoude 2009c, fig. 8.19-1; Photo Restaura).

Fig. 5.48B. Knife and cleaver from Huissen-Loostraat Zuid site A (Van Renswoude 2008a, fig. 9.4; Photo Restaura).

5.6.3 TOOLS

The presence or absence of knives and cleavers was recorded for 29 assemblages from 26 sites (table E5.22). When no illustrations were available, it was not always clear from the description what a tool really looked like. In that case, it was classified as a knife rather than a cleaver. Knives were present in 19 assemblages (with a total of 83, including possible knives). Cleavers were much rarer: they are only found in four assemblages: Geldermalsen-Hondsgemet (two cleavers, both dated to the Middle Roman period; fig. 5.48A), Huissen-Loostraat Zuid site A (fig. 5.48B), Ewijk-Keizershoeve and Utrecht-Wachttoren-Gemeentewerf.

5.7 BIOMETRICAL ANALYSIS

5.7.1 WITHERS HEIGHT

Table 5.5 shows the mean and range for all withers heights that have been calculated for cattle from rural sites, divided into four main periods. The data show an increase in height during the Roman period, which starts in the Early Roman period and is also largest in this period.

	mean (cm)	n	range (cm)
Late Iron Age	108	33	95-117
Early Roman period	114	68	97-140
Middle Roman period	119	99	99-140
Late Roman period	121	52	102-149

Table 5.5. Reconstructed withers height for cattle from rural sites.

In analysing the measurements for sheep or goat, it was assumed that most are sheep, since where it can be established, this species is much more common than goat.[512] Withers height for sheep shows a slight increase in the Early Roman period, but no further change in the Middle Roman period (table 5.6).

	mean (cm)	n	range (cm)
Late Iron Age	58	7	52-64
Early Roman period	60	19	55-66
Middle Roman period	59	22	51-64

Table 5.6. Reconstructed withers height for sheep or goat from rural sites.

Like cattle, the largest increase in withers height of horses is seen in the Early Roman period; withers height continues to increase during the entire Roman period (table 5.7).

	mean (cm)	n	range (cm)
Late Iron Age	123	10	106-134
Early Roman period	133	46	121-153
Early/Middle Roman period	137	33	123-150
Middle Roman period	140	166	120-156
Late Roman period	142	22	128-153

Table 5.7. Reconstructed withers height for horses from rural sites. None of the animal bone assemblages contain positive identifications of mules, but if Johnstone is correct then mules should be present.[513]

[512] See paragraph 5.3.1.

[513] Johnstone 2004.

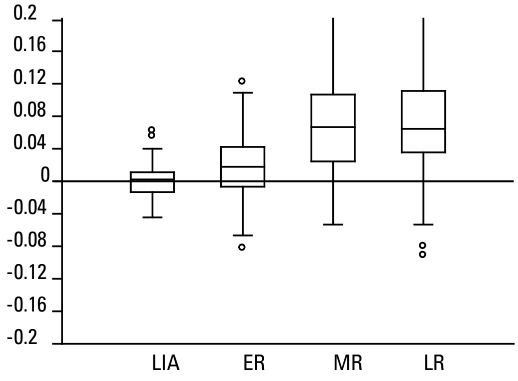

Fig. 5.49. LSI for width measurements for cattle for rural sites, per period. LIA: mainly data from HGM1, n=63; ER: including overlapping phases with LIA, since no difference was visible, n=98; MR: n=215; LR: n=152.

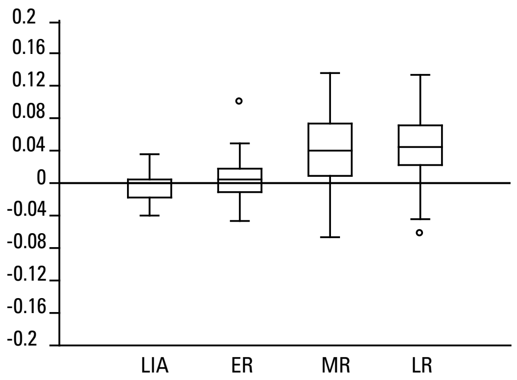

Fig. 5.50. LSI for length measurements for cattle for rural sites, per period. LIA: mainly data from HGM1, n=37; ER: including overlapping phases with LIA, since no difference was visible, n=63; MR: n=140; LR: n=78.

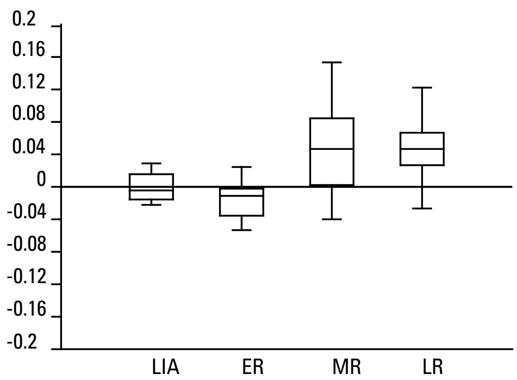

Fig. 5.51. LSI for depth measurements for cattle for rural sites, per period. LIA: data from HGM1, n=23; ER: including overlapping phases with LIA, since no difference was visible, n=11; MR: n=65; LR: n=28.

5.7.2 LOG SIZE INDEX FOR CATTLE

5.7.2.1 Changes over time

Data from rural assemblages from the Late Iron Age and the three main Roman periods were pooled to see if and what changes over time were visible in the log ratios. The data used for the Early Roman period included those from assemblages with an overlapping Late Iron Age/Early Roman date, in order to maximise sample size. A size increase in width, length and depth measurements between the Early Roman and Middle Roman period was observed (figs. 5.49-5.51). The change in all three dimensions was statistically highly significant (table E5.23). Although the mean for all three dimensions increases further in the Late Roman period, this change was not statistically significant. A size increase in width and length is also found in the Early Roman period, but only that in width is statistically highly significant. Depth measurements become smaller in the Early Roman period, but

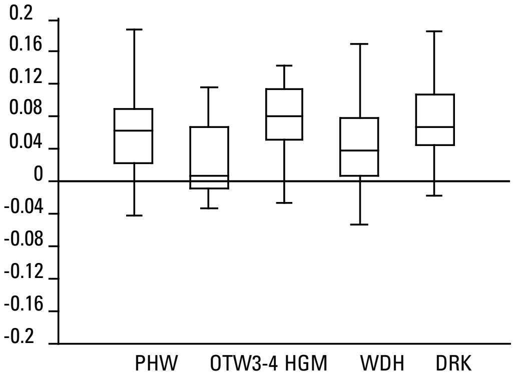

Fig. 5.52. LSI for width measurements for cattle for Middle Roman rural sites, per site. PHW3-6: n=37; OTW3-4: n=19; HGM3-4: n=49; WDH: n=33; DRK2-3: n=59.

this is not statistically significant (fig. 5.51). It is clear that cattle started to increase in size (width and length, but not depth) in the Early Roman period, followed by a further size increase (width, length and depth) in the Middle Roman period. No significant changes occurred in the Late Roman period.

5.7.2.2 Comparison between different rural sites in the Early Roman period

Data on width measurements are available for five rural settlements; data for Utrecht-LR46S and Utrecht-LR41-42 were combined to increase the sample size. There were no significant differences between the sites (table E5.24; fig. E5.31). Length measurements for Tiel-Passewaaijse Hogeweg 2 and Utrecht-LR46S/LR41-42 (the only sites with 10 or more length measurements) show a statistical difference between the two assemblages; length measurements are smaller in Tiel-Passewaaijse Hogeweg (table E5.25; fig. E5.32). Too few depth measurements were available for an analysis.

5.7.2.3 Comparison between different rural sites in the Middle Roman period

Log ratios for width measurements from five rural sites were compared (fig. 5.52). Data from several phases were pooled to increase the data set. In terms of chronology, Tiel-Passewaaijse Hogeweg 3-6 and Geldermalsen-Hondsgemet 3-4 are comparable, and so are the other three sites. The smallest mean is found in Tiel-Oude Tielseweg, while Geldermalsen-Hondsgemet has the largest mean. Several statistically significant differences were found between pairs of assemblages (table E5.26). While a difference in date can explain a size difference between cattle from Geldermalsen-Hondsgemet and cattle from Wijk bij Duurstede-De Horden and Tiel-Oude Tielseweg (we have already seen that cattle withers height increases during the Roman period), this does not explain the differences between Tiel-Passewaaijse Hogeweg and Geldermalsen-Hondsgemet, and between Wijk bij Duurstede-De Horden and Druten-Klepperhei.

Log ratios for length measurements from four sites were compared (fig. E5.33). The largest mean is found in Druten-Klepperhei, and very similar to that in Geldermalsen-Hondsgemet. A statistically highly significant difference was found between these two sites and Wijk bij Duurstede-De Horden (table E5.27). Log ratios for depth measurements from three Middle Roman assemblages show no statistically significant differences (table E5.28; fig. E5.34).

5.7.2.4 Comparison between different rural sites in the Late Roman period

For the Late Roman period, log ratios for width measurements from four assemblages could be compared (fig. E5.35). The only statistically significant difference was found between the adjacent sites Tiel-Oude Tielseweg and Tiel-Passewaaijse Hogeweg, with larger width measurements in the latter site (table E5.29). Length measurements are also largest for Tiel-Passewaaijse Hogeweg and smallest for Tiel-Oude Tielseweg (fig. E5.36), but the difference is not statistically significant (table E5.29). Perhaps this is due to the much smaller sample sizes. Depth measurements will not be discussed, since only Tiel-Passewaaijse Hogeweg yielded more than 10 measurements.

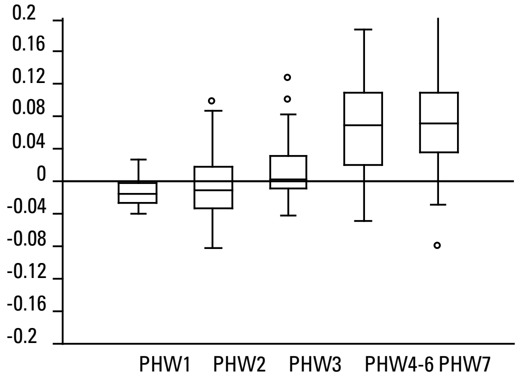

Fig. 5.53. LSI for width, length and depth measurements for cattle from Tiel-Passewaaijse Hogeweg.

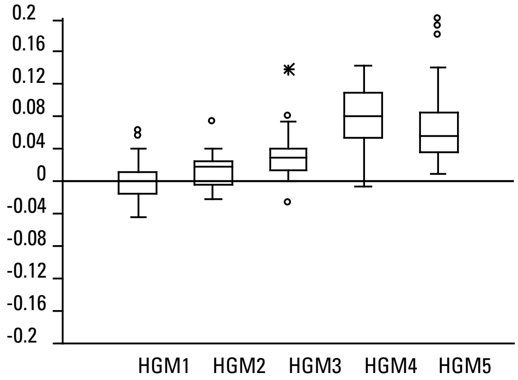

Fig. 5.54. LSI for width, length and depth measurements for cattle from Geldermalsen-Hondsgemet.

5.7.2.5 Changes within sites

For two rural settlements, changes in size of cattle could be traced from the Late Iron Age to the Late Roman period. Measurements from all three dimensions have been combined to increase the sample size. Tiel-Passewaaijse Hogeweg and Geldermalsen-Hondsgemet show a similar development: a gradual increase from the Late Iron Age to the Early Roman period and first part of the Middle Roman period, followed by a more drastic increase around A.D. 150 (figs. 5.53 and 5.54; tables E5.30-31). In the Late Roman period, size remains stable in Tiel-Passewaaijse Hogeweg but decreases in Geldermalsen-Hondsgemet.

5.8 arable farming

5.8.1 archaeobotanical evidence

Data from analysis of botanical macro-remains were available for 38 assemblages from 28 rural sites. For the remaining assemblages, either no archaeobotanical research was carried out or it has not been published. The focus here is on cultivated crops and wild plants that were collected for food.

The main cereal crops are barley, emmer wheat and oat, with barley present in all but one site (table E5.32). Emmer wheat was found in 24 and oat in 23 sites. In most cases, it was not possible to distinguish between wild and cultivated oat, but cultivated oat could be identified in four sites. The absence of the common cereals in some samples is probably related more to a lack of identifiable remains rather than to what was actually grown. Millet is found in ten sites, and einkorn is found at one or two sites. Remains of bread made from emmer wheat were found in Kesteren-De Woerd.[514]

[514] Kooistra/Van Haaster 2001, 311-313.

In a few sites, cereals were present that are very unlikely to have been grown locally. Spelt wheat was found in four sites. Although the identifications are uncertain, bread wheat and foxtail millet are present in one site each. Also with an uncertain identification, rye may have been present in two sites. If rye was imported, it probably came from north of the Rhine.[515] At four sites where rye was not found among the macro-remains, it was present as pollen. In four cases, weeds typical for more southern regions were found, such as corncockle and narrow-fruited cornsalad. These weeds are seen as an indication for the import of cereals.[516] At two sites, spelt wheat was found as well as these exotic weeds.

A number of crops were grown for their oil-rich seeds: rape, gold-of-pleasure, flax, black mustard and opium poppy. Black mustard and rape may also have been eaten as vegetables.[517] Flax is a dual-purpose crop, with both seeds and stems being useful. At one site at least (Zaltbommel-De Wildeman site C, and possibly also Utrecht-LR46S) evidence was found for the processing of flax stems. Opium poppy may also have been used medicinally.[518]

Pulses are found at several sites, with Celtic bean more common than pea (table E5.33). Among the leaf or root vegetables, beet is the most common: it is found at eight sites. Of the herbs, dill and coriander are certainly Roman introductions.[519] Beet and celery both occur naturally in the coastal zone of the Netherlands, but not in the River Area. This is why it is likely that they were introduced as cultivated plants.[520]

Although not strictly related to agriculture, it is worth mentioning wild plants from which fruits were collected, such as hazelnut, dewberry, blackberry, elderberry, sloe and juniper. Juniper is remarkable because it did not grow naturally in the area around the site where it was found, Huissen-Loovelden Het Riet.[521] Most of the Roman finds in the Netherlands come from sites near the coast, where the plant grew in the wild.[522] Cherry is regarded as an indigenous plant in the Netherlands, but is only found archaeologically from the Roman period; the same applies to damson.[523] It is therefore likely that they were cultivated rather than wild trees.

Four plants may have been used medicinally: black henbane, common vervain, catnip and dyer's rocket. The last plant could also be used to dye textiles. Teasel was probably introduced by the Romans, since the earliest finds in the Netherlands date to the Roman period.[524] Hop probably grew as a wild plant in the River Area; it is not certain whether it was collected on purpose.[525] A species that was certainly imported is fig, which is found at three sites.[526] Walnut may have been imported at first, but was probably cultivated locally later in the Roman period.[527]

If we look at the presence of imported or introduced species,[528] most finds are from samples with a Middle Roman or Early to Middle Roman date. The only exception is the site Utrecht-LR46S, where spelt wheat and coriander are found, together with a weed that forms an indication for imported cereals. Although it seems logical to assume a relationship between these early finds and the nearby *castellum*, the sample in which coriander was found predates its construction.[529] No patterns could be detected between the date and the occurrence of the other crops.

Cereals were grown in arable fields located on the stream ridges, and harvested just below the ears.

515 Kooistra 2009c, 227.

516 Kooistra 2009c, 230.

517 Groot/Kooistra 2009, 3.4.3.

518 Kooistra 2009a, 445-446.

519 Bakels/Jacomet 2003, 543; Kooistra 2009c, 223, 226.

520 Personal communication Laura Kooistra.

521 But juniper may have grown on the northern side of the Rhine, on the Pleistocene sandy soils. Personal communication Laura Kooistra.

522 Van Beurden 2011, 115.

523 Personal communication Laura Kooistra.

524 Kooistra 2009a, 441.

525 Van Haaster 2009, 66.

526 Kooistra 2009c, 227.

527 Bakels/Jacomet 2003, 543; Kooistra 2009c, 227; Van der Veen *et al.* 2008.

528 Bread wheat, foxtail millet, spelt wheat, walnut and fig: imported. Dill, coriander, opium poppy: introduced.

529 Kooistra 2010, 278-279.

After the harvest, livestock could graze the stubble and manure the fields at the same time. Cereals were grown as summer crops.[530] Pulses, vegetables and herbs were probably grown in vegetable gardens close to or inside the settlement, since they require more attention and manure than arable crops.[531] There is no evidence for fruit or nut orchards in rural sites in the research area.[532]

Evidence for fodder was found in Wijk bij Duurstede-De Horden, where fodder consisted of a combination of hay, uncleaned cereals and weeds.[533] In Geldermalsen-Hondsgemet, water plants and grass may have been fed to livestock in summer.[534]

5.8.2 The scale of arable farming

The storage capacity of granaries in rural sites forms a good indication for the scale of production, although it has to be born in mind that granaries may not have been full, and may also have been used for other products besides cereals. Granaries in rural sites show a development from the Late Iron Age to the Roman period: whereas granaries in the Late Iron Age are typically small, in the Roman period much larger structures are also found. This suggests an increase in the amount of cereals that was grown.[535] Apart from larger granaries occurring, some also show a different construction, with rows of postholes dug into ditches, rather than a construction consisting of just postholes. This new construction is reminiscent of that of *horrea* found in military camps.[536] Large granaries, built in this new style of construction, are found for instance in Tiel-Passewaaijse Hogeweg, Wijk bij Duurstede-De Horden, Houten-Tiellandt, Houten-Doornkade and Zaltbommel-De Wildeman sites B and C.[537] No conclusion can be drawn from the absence of large granaries, unless a settlement has been excavated in full. Vos suggests that the sites where larger granaries are found functioned as collection sites for surrounding settlements; production and transport of agrarian surpluses of cereals and perhaps also livestock were organised from these sites.[538]

The digging of ditches to create field systems in the late 1st-early 2nd century can perhaps partly be explained by the expansion and drainage of arable land to increase cereal production.[539] Zooarchaeological data can also provide information on arable farming, in the form of mortality profiles for cattle (with large proportions of older cattle seen as indicators for the use of traction and manure) and pathological lesions on cattle bones (again, an indication for the use of cattle for traction). The increase in age of cattle during the Roman period can be seen as a sign of intensification of arable farming.[540] A recent study suggested an increase in the prevalence of palaeopathology from the Late Iron Age to the Roman period, and from the Early to Middle Roman periods.[541] This could be related to the intensification of both animal husbandry and arable farming. Animals may have been stocked at higher densities than before, which could lead to a higher incidence in disease and trauma.

530 Groot/Kooistra 2009, 3.4.1.

531 Groot/Kooistra 2009, 3.4.2, 3.4.3.

532 Groot/Kooistra 2009, 3.4.4.

533 Lange 1990, 118-122.

534 Kooistra 2009a, 442, 447.

535 Groot *et al.* 2009.

536 Heeren 2009, 176.

537 Heeren 2009, 176-178; Vos 2009, 79-85, 257; Veldman 2010, 62-63, 68-70.

538 Vos 2009, 256-257.

539 Groot/Kooistra 2009, 3.2.2.

540 E.g. Peters 1998, 237.

541 Groot in press b.

5.9 DISCUSSION

5.9.1 SPECIES PROPORTIONS

5.9.1.1 The Late Iron Age and Early Roman period

Generally, cattle should be regarded as the most important farm animal in the Dutch River Area, especially when its meat weight is considered. However, in number cattle are sometimes exceeded by sheep. Sheep are already important in some sites during the Late Iron Age/Early Roman period, and their proportion increases further in the Early Roman period. Whereas three out of nine Late Iron Age/Early Roman assemblages show a proportion of sheep of over 20 %, for the Early Roman period this applies to 11 out of 14 assemblages. Sites with a proportion of horse noticeably higher than the average are Wijk bij Duurstede-De Horden (35 %), Lent-Petuniastraat (19 %) and Utrecht-LR35 (17 %). The proportion of pig is generally lower than 10 %, but three exceptions should be mentioned here: Arnhem-Schuytgraaf (19 %), Oosterhout-Van Boetzelaerstraat and Lent-Petuniastraat (both 15.5 %). For the last two sites, the vicinity of Nijmegen could play a role in explaining a higher proportion of pigs, although we cannot say whether the sites would then be breeding pigs for the military and urban markets of Nijmegen, or consuming more pork under the influence of the town.[542]

5.9.1.2 The Middle Roman period

In the transitional phase Early-Middle Roman period (c. A.D. 40-150), sheep decreases from 30 to 25 % overall, while horse increases from 12 to 18 %. Only four out of nine assemblages still have proportions of sheep over 20 %. Five assemblages now show proportions of horse higher than 20 %. All of the four assemblages where a comparison could be made with the previous period show an increase in horse. All assemblages have proportions of pig lower than 10 %.

All data for the Middle Roman period together show a decline in sheep, an increase in horse and little change for cattle and pig. Some Middle Roman assemblages still have high proportions of sheep, such as Tiel-Medel site 6 and Zaltbommel-De Wildeman site B (both 28 %). Most of the five assemblages dated before A.D. 150 show high proportions of sheep (27 to 45 %), and only one assemblage has a high proportion of horse (Kesteren-De Woerd: 21 %). The eight assemblages dated after A.D. 150 all have proportions of horse higher than 20 %. Kesteren-De Woerd is exceptional in continuing to show a high proportion of sheep. One assemblage has a proportion of pig that is noticeably higher than the average: Tiel-Passewaaijse Hogeweg 5-6.

Overall, there was a gradual increase in horses in the later part of the 1st century and the first half of the 2nd century, but horses became really significant after A.D. 150. Three early exceptions are Wijk bij Duurstede-De Horden (Early Roman), Kesteren-De Woerd c (A.D. 70-110/130) and Geldermalsen-Hondsgemet 3 (A.D. 50-150). Two more sites have proportions higher than the average, but seem less exceptional: 1st-century Utrecht-LR35 (17 %) and Lent-Petuniastraat (19 %).

It is clear that there is a general increase in horses in the Dutch River Area in the Middle Roman period, but is it possible to say anything about the extent and the scale of this increase? How many Middle Roman assemblages have a high percentage of horse? And how many do not? To establish this, I have taken the average for the Early Roman period (12.2 %) as a 'normal' proportion of horses in a mixed farming community. Out of 41 Middle Roman and transitional Early/Middle Roman assemblages, 32 assemblages (78 %) show an increase in horse in comparison to the average proportion

[542] Eating more pork is generally regarded as a 'Roman' cultural influence or military preference. E.g. King 1999; Lauwerier 1988, 129-130.

for the Early Roman period. We should probably allow for slight fluctuations in the proportion of horse. Twelve assemblages only show a slight increase (above 12.2 % but below 20 %), but 20 of the 41 assemblages have proportions of horse over 20 %, and 10 over 30 %. Nearly half of all assemblages thus show a substantial increase in horses.

5.9.1.3 The Late Roman period

In the Late Roman period, sheep continues to decline. Horse also decreases, while cattle increases slightly. Pig shows a large increase from 8 to 21 %; five of the eight assemblages have a proportion of pig over 20 %. Only one assemblage has a proportion of sheep that exceeds 10 %: Arnhem-Schuytgraaf. The proportion of horse varies considerably. The proportion of wild mammals increases during the Late Roman period, from 0.5 to 2.4 %. This may reflect an increased availability of game, related to the regeneration of woodland as a result of a decline in population density. However, it can also reflect a need to supplement the diet with game because agrarian production failed to provide enough food.[543]

5.9.2 Exploitation of cattle

During the Roman period, the proportion of cattle surviving into adulthood increases, from 33 % in the Late Iron Age/Early Roman period to 47 % in the Middle Roman period and 45 % in the Late Roman period.[544] Epiphyseal fusion data for cattle show variation between sites, but little development over time. The proportion of unfused epiphyses remains constant at around 26 %. One Early Roman site (Utrecht-LR46S) has a high proportion of calves killed in the first month of life. If this is proof of dairying, then it suggests that cows did not require their calves to be present to be milked.

Although the overall picture for cattle suggests high survival into adulthood, the individual Early/Middle and Middle Roman assemblages show variation. There is little indication for dairying, with few cattle killed before 8 months. Some sites seem to have had a strong focus on meat (e.g. Tiel-Passewaaijse Hogeweg 3, Zaltbommel-De Wildeman sites A and C and Ewijk-Keizershoeve 2; high slaughter rates between 8 and 36 months). Two sites seem to have had a strong focus on the secondary products of cattle (Tiel-Passewaaijse Hogeweg 4-6 and Houten-Overdam; high slaughter rates of cattle in the categories 'young adult' and older). Mandibular age data show some variability in the age at which cattle are slaughtered for meat: most are killed between 18 and 30 months, but slaughter between 8-18 and 30-36 months is common at some sites.

In the Late Roman period, cattle exploitation seems to have focused on products of the living animal, with two of the three assemblages showing slaughter peaks in the oldest age category, and the third in the category 'adult'. Tiel-Passewaaijse Hogeweg 7 shows much higher slaughter rates for meat (8-30 months) than the other two assemblages.

Where it was possible to study developments over time in cattle exploitation within settlements, one site (Tiel-Passewaaijse Hogeweg) shows a development from a focus on meat to one on secondary products from the Early to the Middle Roman period, and back to meat in the Late Roman period. The same shift from meat to secondary products is visible in Geldermalsen-Hondsgemet, but the development here starts earlier and is more gradual. It also continues into the Late Roman period. The later 1st and 2nd century A.D. saw an increased dependence on cattle to support agriculture, which may reflect intensification of cereal production. In the Late Roman period, in Tiel-Passewaaijse Hogeweg the proportion of cattle with a supporting role for agriculture decreases and meat production becomes more important.

543 Thomas/Stallibrass 2008, 9.

544 Based on mandibular age data.

Although it is concluded here that the older slaughter ages of cattle in the Middle Roman period reflect the importance of products of the living animal (manure and traction), an alternative explanation is that younger cattle were selected to be sold in the town, thus causing older animals to be overrepresented. To decide between these two explanations – intensification of arable farming and selling of young cattle for meat – we need to look at the slaughter ages of cattle in consumer sites. Once we have done that (in chapter 6), we can compare the data from the producer and consumer sites and see whether they complement each other (older cattle overrepresented in rural sites, younger cattle overrepresented in consumer sites) or are similar.

Cattle phalanges seem to be slightly underrepresented, especially in the Middle Roman period, which could indicate some production of cattle hides. This probably only occurred on a small scale, as a side-product of local slaughter in rural sites. If this hypothesis is correct, it seems that leather products were no longer made locally. Instead, leather goods must have been bought on the market. This is similar to the inverse relationship between the production of raw wool and local textile production seen in Tiel-Passewaaijse Hogeweg: with an emphasis on wool production came a decline in local textile production.[545] Textile and leather may both have changed from home crafts to more specialised production.

No convincing evidence for brawn production was found. If brawn was produced in rural sites, there would have been a need for suitable containers. A study of locally produced ceramics, in combination with detailed analyses within sites of skeletal element distribution (looking for concentrations of brawn-making waste) may be able to find better evidence in the future.

5.9.3 Exploitation of sheep

Sheep formed an important part of the agricultural economy from the Late Iron Age to the first part of the Middle Roman period, after which the species started to decline in the River Area. In the Late Iron Age and Early Roman period, sheep were mainly kept for meat, with high slaughter rates between 6 and 12 months. It is possible that sheep were milked as well. The main slaughter peak for Geldermalsen-Hondsgemet 2 was found between 2 and 3 years, which suggests a balanced exploitation of meat and wool. Gradual slaughter and higher survival into adulthood was found in Wijk bij Duurstede-De Horden, which indicates a focus on wool. Exploitation of sheep seems to have differed between sites. This is confirmed by the proportions of unfused epiphyses, which show high variability.

In the Middle Roman period, there seems to have been a slight shift in exploitation of sheep towards wool. Tiel-Passewaaijse Hogeweg provides the best evidence for this, but relatively high survival into adulthood is also found at Geldermalsen-Hondsgemet and Huissen-Loostraat Zuid site A. Kesteren-De Woerd c-e and Zaltbommel-De Wildeman site C show a continued focus on meat, with high slaughter rates in the first two years. Wijk bij Duurstede-De Horden, with an early focus on wool, seems to have shifted to an increased focus on meat in the Middle Roman period. Epiphyseal fusion data support a change from meat to wool in the Middle Roman period, with a drop in the proportion of unfused epiphyses from 47 % to 30 %. What is even more interesting is that there seems to have been a shift back to meat production in Tiel-Passewaaijse Hogeweg around the middle of the 2nd century.[546] This shift was not seen at Druten-Klepperhei, the only other site for which data were available for subphases within the Middle Roman period. As mentioned above, Huissen-Loostraat

545 Groot 2008a, 71, 95.

546 The proportion of unfused epiphyses rises again in phase 4 to 52 %.

Zuid site A – which dates in the 3rd century – also shows evidence for wool rather than meat. The shift to wool production at some sites is followed by a general decline in sheep in the region.

Few sites show a strong emphasis on wool.[547] It seems as if meat was always the first priority, with a slight shift in slaughter ages occurring due to a small increase in wool production. The decline in sheep in the 2nd century seems to have gone hand in hand with the rise in horse.

5.9.4 Exploitation of horse

The relatively high proportions of horse in the Middle Roman period indicate that this species played an important role in the agrarian economy. The question is what this role was. It has been suggested before that horses were bred for the Roman army.[548] Before we can interpret the substantial increase in the proportion of horse in the Middle Roman Dutch River Area as proof of breeding surplus horses for the army, however, we need to establish that the increase does not reflect increased meat production or consumption.

In the Late Iron Age/Early Roman period, horses show evidence for high survival into adulthood. This indicates that horses were mainly kept as riding animals. Changes in the ratios of adult and non-adult horses could only be analysed for Tiel-Passewaaijse Hogeweg and Geldermalsen-Hondsgemet. Tiel-Passewaaijse Hogeweg shows much higher proportions of non-adult horses, but the figures come closer together in the period A.D. 120/140-270. This is the period when both sites show the highest proportions of horse, and exploitation seems to be similar at this time. Before A.D. 120/140 and in the Late Roman period, however, horses were exploited in different ways at these sites, or different strategies or management systems were used. Epiphyseal fusion data for Tiel-Passewaaijse Hogeweg and Geldermalsen-Hondsgemet are less different for the period before A.D. 120/140, although Tiel-Passewaaijse Hogeweg still has somewhat higher proportions of non-adult horses. A large increase in the proportion of young horses is observed around A.D. 120/140, supporting the dentition data.

An increase in slaughter of young horses around A.D. 150 is also visible for Druten-Klepperhei. In fact, the overall proportion of unfused epiphyses shows an increase throughout the Roman period (from 10 % in the Early Roman to 20 % in the Middle Roman period and 36 % in the Late Roman period). In the Middle Roman period, this proportion is much more variable than in the Early Roman period. No relationship could be found between the proportion of non-adult horses and a high proportion of horse. Crown height data show high proportions of slaughter of younger adults (5 to 10 years) for most periods. An age of 5 to 10 years seems to be quite young to dispose of breeding stock.

To better understand the exploitation of horses, it may be illuminating to compare data for horse with those for the other domesticates. Table 5.8 shows the proportion of unfused epiphyses for the main domestic species for the Early, Middle and Late Roman periods. Pig, a species that is kept only for meat, has a proportion of unfused epiphyses ranging from 40 to 63 %. This figure can be seen as a rough baseline for meat production.[549] Sheep/goat has a figure within this range for the Early Roman period, confirming that meat was the primary product of sheep in that period. Secondary products of sheep become more important during the Middle Roman period. The proportion of unfused epiphyses for cattle is lower than that for sheep and pig. This suggests that secondary products were important. A contributing factor, however, is that the slaughter age for cattle for meat seems to be

[547] Unlike Northern France, for example, where sheep were exploited for wool in the first place. Lepetz 1996, 87.

[548] Groot 2008a; Hessing 2001, 162; Laarman 1996b, 377; Roymans 1996, 82.

[549] When comparing pigs with the other three species, it must be taken into account that pigs produce much more offspring per year, which means that fewer breeding animals are needed. This would affect the proportion of non-adult animals.

somewhat later than for sheep and pig: 18-30 months for cattle compared to 6-12 months for sheep and 14-21 months for pigs. Not surprisingly, horse has the lowest proportion of all species, but what is interesting is that this proportion increases during the Middle and Late Roman period. In the Middle Roman period, the proportion of unfused epiphyses is not much lower than that for cattle, and in the Late Roman period it is higher.

species	Early Roman	Middle Roman	Late Roman
cattle	26 % (n=1071)	26 % (n=1797)	27 % (n=863)
sheep/goat	47 % (n=554)	30 % (n=394)	-
horse	11 % (n=244)	20 % (n=1129)	36 % (n=235)
pig	63 % (n=131)	45 % (n=207)	40 % (n=357)

Table 5.8. Percentage of unfused epiphyses for the four main domesticates. Totals are a combination of all available data for sites in the Dutch River Area.

Compared to pig, which was only ever kept for meat, the percentage of unfused epiphyses for horse is relatively low, so it is clear that horses were not kept primarily for meat. It is also evident that horse meat was not produced for the market, since we find little or no evidence for consumption of horse meat in army camps and towns.[550] It is possible that hides were used, but Roman finds of horse leather are unknown.[551] Butchery marks are commonly found on horse bones in rural sites, and some are typical for preparation and consumption of meat.[552] It is therefore undeniable that horse meat was eaten in the rural settlements in the Dutch River Area; however, this did not occur in all settlements, and probably only occasionally. After all, horse burials are more common than those of cattle and horse bones are generally less fragmented.

A better explanation for the increase in slaughter of young horses is related to the breeding of horses for use as riding or transport animals. The army needed a regular supply of horses to replace the ones that were old or injured, and had strict requirements. Any horses bred in the rural sites that did not meet these requirements, and were therefore also not suitable to keep for breeding, were probably culled. In some cases, it may have been clear that horses were unsuitable at a young age – reflecting the rising proportion of unfused epiphyses – but in others, this may only have been found out once the horses were receiving their training – reflecting the 5-to-10-year-olds. This latter group may also consist of animals retained as breeding stock that either did not make the grade or were infertile. With culling of horses, it seems only natural that some of this supply of meat was consumed. That proportions of young horses in the rural sites are not higher can be explained by an extensive form of management.[553]

5.9.5 Exploitation of pig

Overall, the mandibular data for sites in the Dutch River Area show a very clear pattern of slaughter of pigs in the second year of life, between 14 and 21 months. No development through time could be identified. Some variability is found between sites, but considering the small sample size, no great value should be attached to these differences. The drop in the proportion of unfused epiphyses for pigs

[550] The proportion of horse fragments is generally low in military and urban sites, with the exception of Late Roman Nijmegen-Valkhof. See chapter 6.

[551] See paragraph 4.4.

[552] Esser 2013; Groot 2009a, 362, 386-387; Laarman 1996a; Taayke 1984; Zeiler 2005. See also paragraph 5.6.2.

[553] Groot 2008a, 82-83.

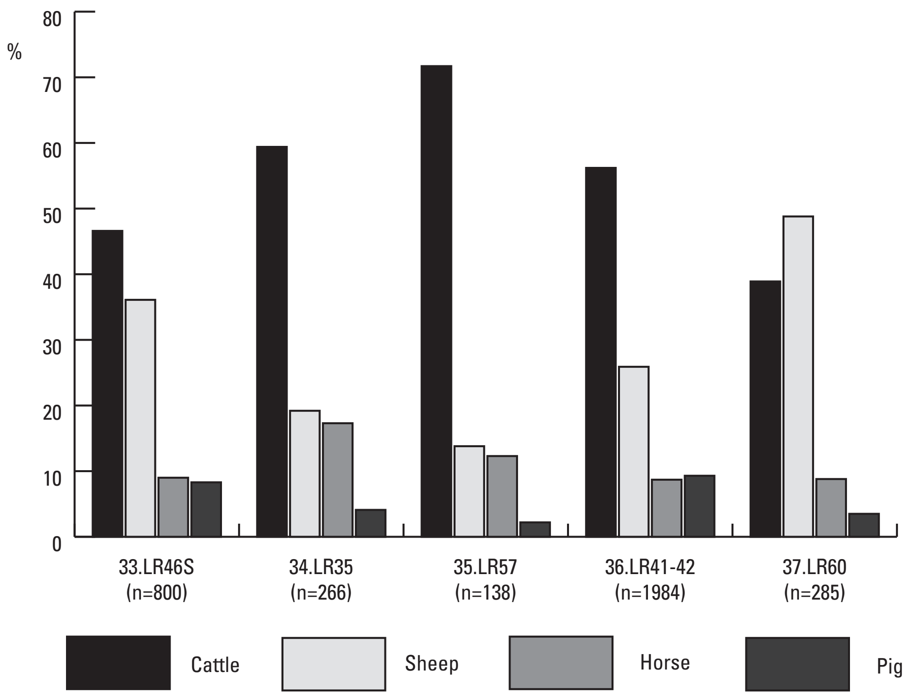

Fig. 5.55. Proportions for the four main domesticates for Early Roman rural sites in Utrecht-Leidsche Rijn (based on the number of fragments).

during the Roman period (from 63 % in the Early Roman period to 45 % in the Middle Roman period and 39.5 % in the Late Roman period), however, is a significant development (table 5.8). This could indicate an intensification of pork production. When more young pigs are sold outside the settlement for meat, older breeding stock should be overrepresented, and increase the average age. It is not clear why this would not show up in the mandible data. One way to test whether this is true is to compare slaughter ages from rural sites with those from consumer sites. This will be done in paragraph 7.2.5.

5.9.6 Differentiation in animal husbandry

5.9.6.1 Differentiation between neighbouring sites

In several cases, animal bone assemblages were available for sites that are located close together and have similar chronologies. This provided an opportunity to analyse differences in animal husbandry between neighbouring settlements. Presumably, in these cases environmental differences are not a factor, although the actual site territories of these settlements may have differed slightly in their suitability for different types of animal husbandry. Three examples will be discussed in this paragraph: several Early Roman sites in Utrecht-Leidsche Rijn, three Middle Roman sites in Zaltbommel-De Wildeman, and Tiel-Passewaaijse Hogeweg and Tiel-Oude Tielseweg throughout the Roman period. Any bias from recovery is likely to be small, since the sites that are compared are close together with similar geology, and were generally excavated by the same team using similar excavation methods.

Five sites in Utrecht-Leidsche Rijn are all dated to the Early Roman period. The main difference lies in the proportions of sheep and cattle (fig. 5.55). Three sites have sheep proportions of over 20 %. There does not appear to be any correspondence between the differences and the dates of the sites. Wild mammals are absent in Utrecht-LR57 and Utrecht-LR35, present in Utrecht-LR60 (0.4 %), Utrecht-LR46S (0.6 %) and best represented in Utrecht-LR41-42 (1.4 %). Of the two Leidsche

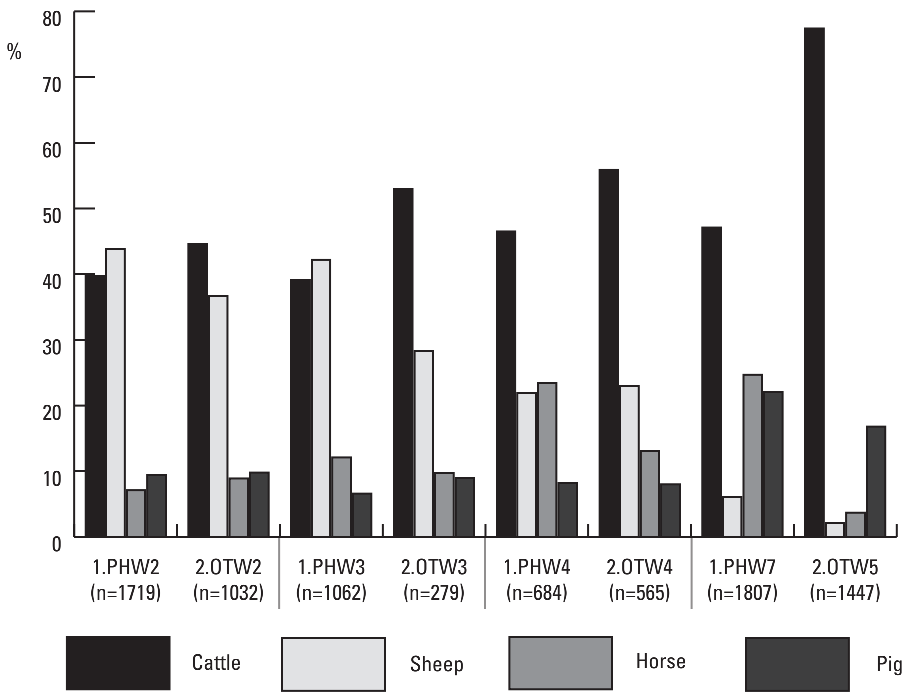

Fig. 5.56. Proportions for the four main domesticates for adjacent rural sites in Tiel (based on the number of fragments). PHW2 overlaps with the Late Iron Age.

Rijn sites with mandibular age data for cattle, Utrecht-LR46S shows a large peak in the category 0-1 months, whereas Utrecht-LR41-42 has its main peak between 18 and 30 months. Survival beyond 3 years is slightly higher for Utrecht-LR46S than for Utrecht-LR41-42. Cattle were exploited for dairy products and meat, but the ratio between these products differs between the two sites. Utrecht-LR46S and Utrecht-LR60 show very similar mortality profiles for sheep, with high slaughter rates in the first two years and low survival beyond 4 years. Utrecht-LR41-42 is broadly similar, but has slightly better survival rates for sheep. Sheep were mainly exploited for meat.

The two adjacent sites in Tiel can be studied for most of the Roman period, with the exception of the 100 years between A.D. 170 and 270, when Tiel-Oude Tielseweg was not inhabited. For the Late Iron Age/Roman period, the species proportions are very similar, with only small differences in the proportions of cattle and sheep (fig. 5.56). Differences in phase 3 occur in the proportions of sheep and cattle: the percentage of sheep is much higher in Passewaaijse Hogeweg and the percentage of cattle lower. In phase 4, the percentage of horse increases significantly in Passewaaijse Hogeweg but much less so in Oude Tielseweg. This could be related to the end of this phase in Oude Tielseweg around A.D. 170, since horse breeding in most sites does not seem to start in earnest until around A.D. 150. In the Late Roman period, there are clear differences between the sites: Oude Tielseweg has a very high percentage of cattle, 17 % pig, and very few sheep and horses. In Passewaaijse Hogeweg, horse is well represented with 25 %, and the percentage of pig is higher than that in Oude Tielseweg; as a consequence, the proportion of cattle is much lower. Wild mammals are more common in Oude Tielseweg in phases 3 and 4, but absent in phase 2, when they are found in Passewaaijse Hogeweg. For cattle only the proportion of unfused epiphyses could be compared. Slaughter rates of young cattle are similar in the Early Roman period, but differ more in the Middle Roman period. The difference increases further in the Late Roman period. The proportion of unfused epiphyses for sheep is much higher in Passewaaijse Hogeweg in the Early Roman period. In the earlier part of the Middle Roman period, the proportions are closer to each other, suggesting a similar exploitation of sheep at this time.

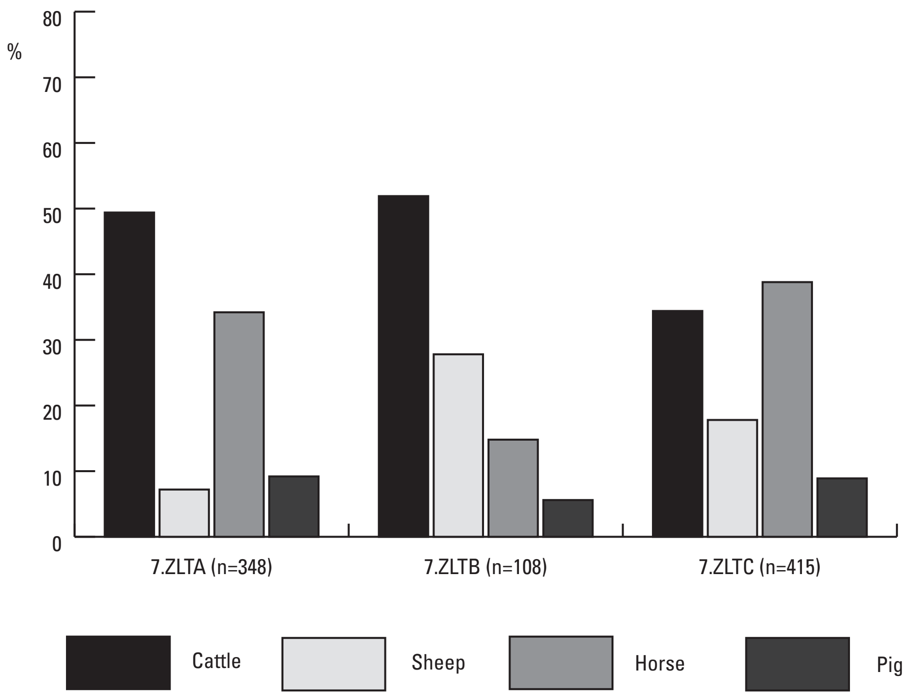

Fig. 5.57. Proportions for the four main domesticates for three adjacent Middle Roman sites in Zaltbommel-De Wildeman (based on the number of fragments). ZLTA: only Middle Roman material included here.

Cattle from the two settlements in Tiel show differences in size, which are most noticeable in the width measurements from the Late Roman period.

Three sites were excavated in Zaltbommel-De Wildeman, assemblages from two of which are contemporaneous (A.D. 70-200). Site C dates slightly earlier than sites A and B. Site C has a very high proportion of horse (39 %), especially when the date is considered (fig. 5.57). The percentage of sheep of 18 % is more typical for this period. Site A also has a high proportion of horse, but very few sheep, while site B has a high percentage of sheep (28 %) and a relatively low percentage of horse. No wild mammals were found. No age data could be compared for the sites in Zaltbommel-De Wildeman.

How can these differences be explained? As stated above, the potential of the landscape is not the obvious explanation in this case. A second explanation is that the sites discussed are complementary sites and practised local exchange of agrarian products. This may or may not have involved a site hierarchy. Next, the variation in species proportions may reflect different relative specialisation oriented towards the market. The structures do not provide any clear indications for such differences; for example, granaries are found at all three sites in Zaltbommel-De Wildeman.[554] While larger granaries were present in Tiel-Passewaaijse Hogeweg but not in Tiel-Oude Tielseweg, the latter settlement was not excavated in full, so it is possible that they were simply missed. Very few or no structures were excavated in some of the sites in Leidsche Rijn, so nothing can be said on this topic.

A fourth explanation is differing relations to nearby consumer sites. The 1st-century settlements in Leidsche Rijn all show indications for close relations with the military, but there are differences, which do not seem to be related to the distance from consumer sites (in this case the *castellum* De Meern),[555] but rather to the strength of the military connections.[556] A final explanation could be a difference in

[554] Veldman 2010.

[555] *Castellum* Vechten was located about 7 km upstream from the start of our era, while *castellum* De Meern was even closer.

[556] Langeveld 2010a, 324, 327.

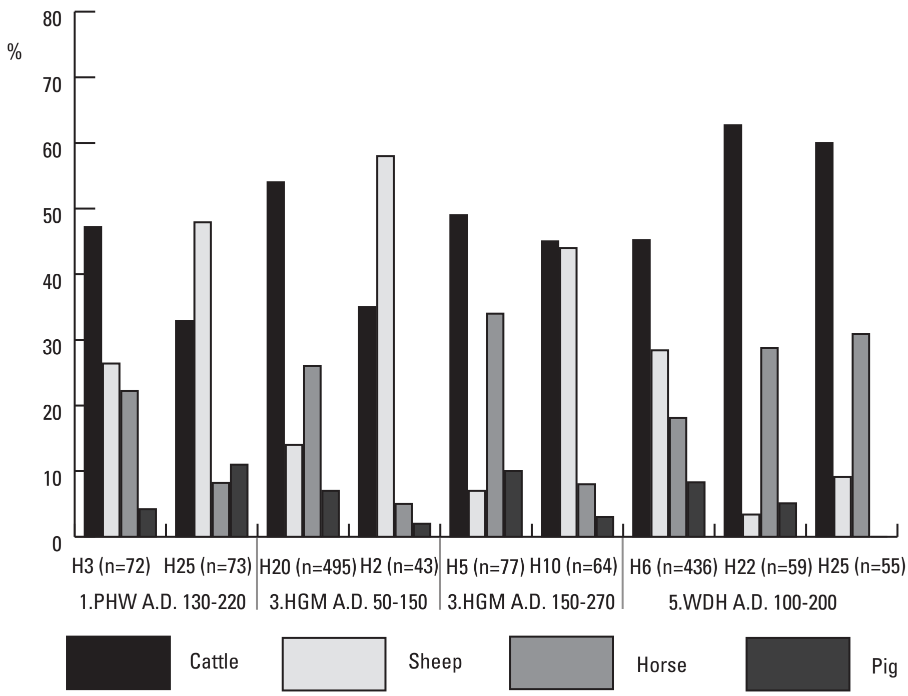

Fig. 5.58. Proportions for the four main domesticates per household for three rural settlements in the Middle Roman period (based on the number of fragments).

ethnicity and accompanying difference in food preference or animal husbandry; this could perhaps explain the differences in Late Roman Tiel. At the moment, it is not possible to say with certainty which explanation is most likely.

5.9.6.2 Differentiation within rural settlements

Analysing animal bone assemblages for individual farms within a settlement can give further insight into the variation in animal husbandry practices. An analysis at household level was carried out for three settlements in the Dutch River Area.[557] Species proportions per household show a relatively high proportion of either sheep or horse (fig. 5.58).[558] The houses with high proportions of horse (22-34 %) all had low proportions of sheep/goat (3-14 % with one exception of 26 %), while the houses with high proportions of sheep (44-58 % in Tiel-Passewaaijse Hogeweg and Geldermalsen-Hondsgemet and 28 % in Wijk bij Duurstede-De Horden) all had low proportions of horse (5-8 % in the first two sites and 18 % in Wijk bij Duurstede-De Horden). For Tiel-Passewaaijse Hogeweg and Geldermalsen-Hondsgemet, the three houses with a high proportion of horse all showed indications that a veteran lived there, based on the presence and number of *militaria* (fragments of *lorica segmentata* and horse gear) and the building style of the house. This suggests a link between horse breeding and returned veterans. Horse breeding may have been initiated and controlled by veterans. It is not surprising that the breeding of horses, which were destined for the Roman army, was controlled by people who had connections in the army. Meanwhile, for other households horse breeding was not an option, and they continued the local animal husbandry tradition of keeping sheep.

557 Groot 2011b; 2012b.

558 Relative because cattle is the dominant species in most households. Of course, the problem with using proportions is that a high proportion of horse could also mean the same number of horses, but fewer sheep.

Some of the sites included in this chapter as rural sites are *villa* or *villa*-like settlements, while others show some characteristics of military sites. They will be discussed separately in this paragraph to see if they differ from the other rural settlements with regard to agrarian production and food consumption.

5.9.7.1 Villa sites

Several of the rural sites in this study have been interpreted as *villae*. While they differ from the *villae* in the loess zone, they show some characteristics that distinguish them from the typical rural settlement in the Dutch River Area. Druten-Klepperhei shows a *villa*-like lay-out and has a stone bathhouse.[559] Ewijk-Keizershoeve probably had a stone main building, although this has not been excavated.[560] Not much is known about Lent-Petuniastraat/Steltsestraat, but both sites are believed to have been part of a *villa* complex.[561]

With regard to species proportions, Ewijk-Keizershoeve 2 (the phase of the *villa*) is not remarkable. Druten-Klepperhei 2 has a high proportion of cattle compared to contemporary sites, and a low proportion of sheep (fig. E5.2). Druten-Klepperhei 3 has a high proportion of horse when it is compared to contemporary sites (fig. 5.9).[562] Lent-Petuniastraat and Lent-Steltsestraat fit into the pattern of the other rural sites in the 1st century. In the 2nd/3rd centuries, the proportion of cattle for Lent-Steltsestraat is relatively high and that of sheep relatively low. Because the individual rural sites show so much variation, it is difficult to say if the *villa* sites are different or not. Game is found in Druten-Klepperhei and Ewijk-Keizershoeve, and in the Middle Roman period, the percentages are higher than the average for all the rural sites. Chicken is also present in both these *villae*, although in Druten-Klepperhei only in the earliest phase. Its absence in Lent-Petuniastraat/Steltsestraat can be related to the small size of the assemblages. Wild birds have been found in Ewijk-Keizershoeve and Druten-Klepperhei, but not in larger quantities than in other rural settlements. The presence of oysters in the *villa* phases of Ewijk-Keizershoeve and Druten-Klepperhei (phases 2 and 3) is interesting, since oysters are rare in rural settlements.[563]

The exploitation of livestock does not show a clear pattern. The proportion of unfused epiphyses for cattle is low in Ewijk-Keizershoeve 3, but high in Druten-Klepperhei 2 and average in Druten-Klepperhei 3. Both sheep and horse show low proportions of unfused epiphyses in Druten-Klepperhei, sheep in both *villa* phases and horse only in Druten-Klepperhei 2. Archaeobotanical data are only available for Ewijk-Keizershoeve. No imported cereals were found here. Several Roman herbs are present: opium poppy, celery, perhaps chives and dill (pollen).[564] However, with the exception of chives, these are also found in other rural settlements.

To conclude, the *villa* sites show very few distinguishing characteristics. The only thing which sets them apart from the other rural settlements is oysters, but even these are found in a few other sites.

5.9.7.2 Sites with a military flavour

Huissen-Loostraat Zuid sites A and D, Huissen-Loovelden Het Riet and Huissen-Loovelden Riolering have some military characteristics: V-shaped ditches in all sites, *militaria* in Huissen-Loostraat Zuid and a typically military coin spectrum in Huissen-Loovelden Het Riet.[565] Three of the assemblages

559 Hulst 1978; 1980.

560 Blom/Veldman 2012, 14-15.

561 Whittaker 2002.

562 Druten-Wilhelminastraat has an even higher proportion, but is part of the same site as Druten-Klepperhei and is probably not representative.

563 They were found in three other rural sites.

564 Brijker *et al.* 2012.

565 Kemmers 2011, 89; Roessingh/Blom 2011; Schurmans 2008; Van Renswoude 2008a.

are part of the same settlement. Little is known about Arnhem-Schuytgraaf, but it has been suggested that this is a military rather than a rural site.[566]

The species proportions for Huissen-Loostraat Zuid sites A and D are not remarkable. Huissen-Loovelden Het Riet and Huissen-Loovelden Riolering both have high percentages of cattle. Arnhem-Schuytgraaf has a high proportion of pig in the Middle Roman period. Game is found in higher percentages than average in Early Roman Arnhem-Schuytgraaf, Huissen-Loostraat Zuid site D and Huissen-Loovelden Het Riet. Chicken is present in Middle Roman Arnhem-Schuytgraaf. A few remains of wild birds were found in the same site, as well as in Huissen-Loostraat Zuid site D. Oysters were not found in any of the sites.

As for the *villa* sites, the exploitation of livestock is not remarkable or really different from that in other rural settlements. The proportion of unfused epiphyses for cattle is low in Huissen-Loostraat Zuid site A, but average in Huissen-Loovelden Het Riet and Middle Roman Arnhem-Schuytgraaf. The proportion of unfused epiphyses for horse is high in Huissen-Loostraat Zuid site A, which suggests breeding of horses. The sites in Huissen-Loostraat Zuid show several imported crops: spelt wheat in Huissen-Loostraat Zuid site D and fig and perhaps bread wheat in Huissen-Loostraat Zuid site A.[567] However, such finds also occur in other rural settlements.

To conclude, there is little about the animal bone assemblages that would suggest a military rather than a rural character of the sites, apart from perhaps the high proportions of cattle and pig.

5.9.8 Butchery methods

The percentage of butchery marks on cattle bones did not show any changes over time, but is very variable between individual assemblages. The chop-cut ratio also varies between assemblages, but seems to show an increase during the Roman period (fig. 5.37). The analysis of the proportions of chopped-through marks and superficial chop marks provided ambivalent results, with changes over time in Geldermalsen-Hondsgemet which were not found for other sites. The presence of cleavers in four sites, all dated to the Middle Roman period, and not found in earlier periods, indicates that new tools had become available. With these new tools, it was possible to change butchery practices (fig. 5.59). However, although butchery methods certainly changed, with an increase of the use of the cleaver and the chopping through bone, butchery still appears traditional when compared to that described for Roman urban contexts.[568] The butchery marks on cattle bones from Middle Roman Geldermalsen-Hondsgemet show a combination of traditional and new butchery methods, with knife cuts remaining common, and the crude chopping through bones much less common than in urban and military contexts. This is not altogether surprising, since the Roman butchery methods found in towns were intrinsically linked with the large-scale processing of cattle, not only providing meat but also marrow and grease. This processing was carried out by specialists. On a rural site, it is very unlikely that cattle would have been butchered by specialists; moreover, the scale was very different, as well as the needs of the rural population. Nevertheless, some new elements appear in butchery. Seetah suggested that the new butchery methods may have originated in the Roman army, with military butchers being the most likely to develop knowledge about efficient dismemberment. Urban butchers may have been ex-army personnel.[569] Since butchery methods also changed in rural sites, this may be one more type of change that can be attributed to veterans, who are seen as mediators of Roman ideas and practices, responsible for spreading literacy, Roman building techniques and styles and new styles

566 Personal communication Stijn Heeren.

567 Hänninen/Kooistra 2008.

568 E.g. Dobney *et al.* 1996; Maltby 1989; 2010; Peters 1998.

569 Seetah 2006, 115-116.

Fig. 5.59. Changes in butchery methods.

of clothing and eating.[570] Veterans may have observed how cattle were butchered in the army camps, and introduced the specialist butchery tools in rural sites when they returned there.

The presence of shoulderblades with perforated blades and typical cut marks suggests that smoked shoulders of beef were consumed in rural sites; however, it is unclear whether they would have been prepared locally or acquired on the market. There is certainly evidence that smoking shoulders of beef was practised in the Netherlands long before the arrival of the Romans.[571] The typical ovens for smoking meat on a larger scale which are known from Roman Switzerland have not been found in the Roman Netherlands.[572] Perhaps smoking meat was only practised at a household level and not at an industrial one. Scoop marks on shafts of limb bones, which have been interpreted as an indication for smoked or dried meat, are rare, but this may also be related to a lesser use of the cleaver compared with urban and military sites.[573]

Butchery marks on horse bones occur in nearly every rural site. However, the total percentage of butchery per period is lower than that for cattle. Fragmentation of horse bones can be similar to that of cattle bones, but is often lower. Gnawing marks are slightly more common on horse bones, but not enough to support the explanation that horses were butchered only to provide meat for dogs. Some butchery marks clearly indicate consumption of horse meat. Overall, it seems that horse meat was certainly consumed in rural sites, but that horses were slaughtered less often than cattle. Consumption of horse meat in a ritual context has been suggested, as have food shortages,[574] but butchery marks seem

570 Derks/Roymans 2002; 2006; Heeren 2009, 252-256; Vos 2009, 242-251.

571 Van Mensch/IJzereef 1977.

572 Deschler-Erb 2013.

573 Kunst 2006.

574 Lauwerier 1999.

too common for these explanations. A third explanation, that of butchers passing off horse meat as something else, is unlikely for rural sites, where the slaughtering of an animal would have been difficult to hide, and the meat was consumed by family and neighbours. The number of recorded butchery marks for horse is too small to establish whether butchery methods changed over time.

5.9.9 BIOMETRICAL ANALYSIS

5.9.9.1 Changes over time

Withers heights of cattle, horse and sheep all increase during the Early Roman period, although in the case of sheep the increase was very slight and may hardly have been noticeable. Horses continue to increase in size during the Roman period and reach an average withers height of 140 cm during the Middle Roman period, more than 16 cm more than the average for the Late Iron Age. An earlier study identified a difference in size between horses from rural sites and those from military and urban sites, but claimed that no size increase occurred over time.[575] Size increases of up to 15 cm in withers height have been observed for other parts of Western and Central Europe.[576]

The overall increase for cattle is smaller, with an average for the Middle Roman period of 118.5 cm, 10 cm more than the average for the Late Iron Age. The main increase in cattle withers height occurred in the Early Roman period.

Although the small change in withers height of sheep suggests that no drastic changes in sheep populations occurred, there is one indication that genetic changes may have taken place. The presence or absence of a second foramen in sheep/goat mandibles – a non-metric trait – was systematically recorded for the Geldermalsen-Hondsgemet and Tiel-Passewaaijse Hogeweg assemblages. The extra foramen was recorded in the belief that the ratio of absence-presence had a genetic basis and would hold potential for analysing changes in herd composition. The presence of the extra foramen increases in both sites in the Early Roman period, followed by a decrease from around A.D. 50 (table 5.9). Data from Springhead, England also show a change in prevalence around the transition from the Iron Age to Roman period, suggesting that this is a wider phenomenon.[577] Perhaps a new type of sheep was imported to Northwestern Europe, but one that was similar in size to the local type. On the other hand, Albarella and colleagues noted a significant increase in sheep size in the Middle Roman period in a site in Essex, probably related to the introduction of new stock.[578]

phase	n foramen recorded	n extra foramen present	% present
Geldermalsen-HGM 1	18	4	22
Geldermalsen-HGM 2	15	13	87
Geldermalsen-HGM 3-4	23	13	57
total	**56**	**30**	**54**
Tiel-PHW 1	8	4	50
Tiel-PHW 2	31	23	74
Tiel-PHW 3-7	24	16	67
total	**63**	**43**	**68**

Table 5.9. The presence of an extra foramen in sheep/goat mandibles in Geldermalsen-Hondsgemet and Tiel-Passewaaijse Hogeweg.

575 Lauwerier/Robeerst 2001.

576 Johnstone 2008, 135; Junkelmann 1990, 39.

577 Personal communication Jessica Grimm.

578 Albarella *et al.* 2008, 1836.

Log ratios for cattle also show a size increase, starting in the Early Roman period and continuing in the Middle Roman period. The size increase is visible in width, length and depth measurements, although the latter only in the Middle Roman period. Size increases in Roman livestock have been interpreted as either `improvement` of local animals or import of new stock.[579] However, other explanations should be ruled out first.

Better nutrition of Roman-period cattle cannot be ruled out. It is unlikely that the quality of pasture would have changed much. Stabled livestock must be provided with fodder, so it is possible that a change in stabling practices had an effect on nutrition. However, no change in stabling is observed, with the same type of farmhouses with a byre section occurring in the Late Iron Age and Roman period. If nutrition played a role, then it is not a difference between stabling or not stabling, but rather a change in the fodder that was fed to stabled cattle. Unfortunately, there are very few indications for fodder in the research area. In Geldermalsen-Hondsgemet, archaeobotanical indicators suggest the use of water plants and grass as fodder, but it cannot be excluded that the plant remains stem from manure instead of fodder; if they do represent fodder, they indicate extra feeding in summer.[580] Cereals such as barley may have been used as fodder, but are more likely to have been sold as agrarian surplus.[581] In Middle Roman Wijk bij Duurstede-De Horden, livestock was fed hay, uncleaned cereals and weeds.[582] Hay became especially important here in the Middle Roman period, but may have been sold rather than fed to local livestock.[583] Comparing postcranial and tooth measurements could perhaps have indicated whether nutrition was a factor in the size increase, but unfortunately, not enough tooth measurements were available. According to Pucher, the effect of improved nutrition on size is limited and has been overestimated in Roman studies, so perhaps we should look at other explanations.[584]

A shift in the proportion of cows, bulls and steers could also cause a change in size, with more male animals resulting in larger measurements. Mortality profiles suggest a move during the Roman period towards a larger emphasis on traction. In theory, this could mean more males than females, whereas in meat production there is usually an emphasis on adult females (in the living herd), since most males are killed for meat before adulthood. However, the sex determinations for cattle – admittedly few – show no change in the proportion between the sexes, with cows being much more common than bulls or steers.[585] Moreover, since size increases are visible in all three anatomical planes, a shift in the proportion males-females is unlikely.[586]

This brings us back to the original explanations: selective breeding for larger animals or import of new, larger cattle with possible interbreeding with local cattle. A possible indication for a change in genetic composition of cattle is the prevalence of three congenital (non-metric) traits: the absence of the hypoconulid in the third lower molar, the absence of the second lower premolar and the presence of an extra foramen in the mandible. Table 5.10 lists the prevalence of these traits for cattle from Geldermalsen-Hondsgemet. Prevalence of an absent hypoconulid is higher in the Roman period, while prevalence of an absent second premolar or an extra foramen is lower. More data are needed to confirm this trend, but this could support the hypothesis that new animals, with a different genetic background, were introduced in the Dutch River Area in the Roman period.

579 Filean 2006, 421; Lauwerier 1988, 169; Robeerst 2005a, 84-86.

580 Groot/Kooistra 2009; Kooistra 2009a, 442, 447. Plant remains in coprolites from cattle or pigs from Kesteren-De Woerd indate that livestock were either grazed on wet grassland or that fodder was collected there. Kooistra/Van Haaster 2001.

581 Vossen/Groot 2009.

582 Lange 1990, 118-122.

583 Lange 1990, 140.

584 Pucher 2013, 29.

585 See paragraph 5.4.1.

586 Thomas 2005, 79.

Selective breeding of local cattle may also have occurred, but again, Pucher believes that this would not result in dramatic changes.[587] The introduction of new breeding stock and perhaps also interbreeding with the local cattle is much more likely. Where these new cattle came from cannot be answered at the moment. An indication that the local type of cattle continued to exist is formed by the absence of an increase in the minimum values.[588] However, the smaller values are rare, and most of the data displays a large shift to a larger size. Import of larger cattle and subsequent interbreeding with local cattle seems the likeliest scenario.

anomaly	Late Iron Age		Roman period	
	prevalence	n	prevalence	n
absent P2i	10 %	21	4 %	24
abnormal M3i	6 %	17	13 %	24
extra foramen	20 %	15	9 %	35

Table 5.10. Prevalence of three non-metric traits in cattle mandibles from Geldermalsen-Hondsgemet, and the total number of mandibles for which presence/absence was recorded. From Groot in press b.

Size increases in livestock have been observed in various parts of the Roman Empire, for instance Northern Switzerland, Germany, Northern France, England, the Iberian Peninsula and Mallorca.[589] In Northern Switzerland, the size increase of cattle already started during the Late Iron Age and has been associated with elite sites.[590] The highly specialised cattle of alpine Austria show no change in size or type, which can be explained by the demands of their environment. Here, increased body size would only be a disadvantage.[591] In our research area, larger cattle may have been desirable because they would provide more meat per animal, or because they would be more powerful as traction animals.

5.9.9.2 Differences between sites

While the size increase in cattle is not a new discovery, but rather confirms existing views, this study has resulted in an additional conclusion: a comparison between log ratios from contemporary rural sites showed differences in the cattle populations from these sites. In the Early Roman period, the cattle from Utrecht-Leidsche Rijn were taller than the cattle from Tiel-Passewaaijse Hogeweg. However, this can perhaps be explained by the wider range of the phase in Tiel-Passewaaijse Hogeweg, which includes the last decades of the Late Iron Age. Alternatively, it could reflect either the immigration of people from the northern Netherlands, with their cattle, or early contacts with the army; archaeological indications exist for both these factors.[592]

The Middle Roman period provides better evidence for variety in cattle from different sites. Differences in width were found between several pairs of contemporary assemblages (Druten-Klepperhei and Tiel-Oude Tielseweg, Druten-Klepperhei and Wijk bij Duurstede-De Horden, Geldermalsen-Hondsgemet and Tiel-Passewaaijse Hogeweg), and differences in length between two contemporary sites: Druten-Klepperhei and Wijk bij Duurstede-De Horden. Other differences between sites with slightly different dates may be explained by the increasing size of cattle in the Roman period, and should not be given too much weight. The differences in cattle size can be explained by the different trajectories of developments in animal husbandry followed by different communities. Druten-Klep-

587 Pucher 2013, 29.

588 The minimum withers heights do show a slight increase in the lowest value.

589 Albarella *et al.* 2008; Colominas *et al.* 2014; Dobney *et al.* 1996, 31-33; Johnstone 2004; Lepetz 1996; Peters 1998; Schibler/Schlumbaum 2007; Schlumbaum *et al.* 2003; Teichert 1984; Valenzuela *et al.* 2013.

590 Stopp 2011, 364-366.

591 Pucher 2013.

592 Langeveld 2010.

perhei is not an ordinary settlement: it is *villa*-like in its lay-out and has a bathhouse. It is also located close to Nijmegen. Both because of the location and the connections of its owner, this site may have had better access to larger imported cattle than other sites. While this explanation may explain the differences between Druten-Klepperhei and Tiel-Oude Tielseweg and Wijk bij Duurstede-De Horden, it cannot explain those between Geldermalsen-Hondsgemet and Tiel-Passewaaijse Hogeweg, which are very similar settlements. Albarella *et al.* also found differences in livestock size in contemporary sites, but here they can be explained by a difference in economic function of the sites (small town-*villa*-urban centre).[593]

For the Late Roman period, width measurements from Tiel-Passewaaijse Hogeweg are larger than those from Tiel-Oude Tielseweg. Although these are adjacent settlements, they seem to have had separate populations of cattle. Since the Late Roman period is characterised by ethnic changes, with people from north of the *limes* moving to the River Area, these sites were perhaps inhabited by different groups of people, each with their own type of cattle.

Overall, the data for the Middle and Late Roman period seem to suggest that little interbreeding occurred between the different populations of cattle, even with sites located close together.

5.9.9.3 Conclusion

This new study of measurements has confirmed the size increase of livestock noted in earlier studies, and shown that it already occurred in the Early Roman period. It further demonstrated that the size increase was not limited to cattle, but also occurred in horses. It has also revealed intriguing differences between contemporary sites. Unfortunately, due to the relative scarcity of biometric data for the Dutch River Area, only a few sites could be compared.[594] Although the amount of data has been increased by not limiting the analysis to length measurements of complete bones, large assemblages still offer the best potential. Hopefully, the outcome of this study will highlight the potential of biometric analysis.

[593] Albarella *et al.* 2008, 1833-1836.

[594] This scarcity can be explained by a traditional focus on withers height at the expense of other metric data, and by the pressures of modern developer-funded archaeology, limiting the time of analysis and the space available for publishing primary data.

6. Consumers: urban, military and temple sites

This chapter discusses the zooarchaeological evidence from consumer sites. The term consumer site refers to any site where agrarian production is not the main activity. The assumption is that the consumer sites formed the market for any agrarian surplus produced in the rural sites discussed in chapter 5. Although consumer sites thus mainly provide information about consumption, they also provide indirect evidence for production in rural sites. At the same time, consumer sites also fulfilled a role in production, not so much of primary agrarian products, but of processed products, such as textiles, worked bone and horn, leather, grease and meat. Much of these products would have remained within the site itself, but some may have been traded back to the rural sites.
Consumer sites in the research area have been divided into four categories:

1. military sites: including a legionary fortress, *castella*, watchtowers and a military supply base.
2. urban/military sites: the *canabae legionis* in Nijmegen and *vici* adjacent to *castella*.
3. urban sites: there is only one urban centre in the research area, so all the urban data come from Nijmegen.
4. temples: including three rural temples and one urban temple.

This chapter is structured in the same way as the previous chapter, and will successively discuss taphonomy, species proportions, age and sex, skeletal elements, butchery, biometrics and archaeobotanical data. All these data will first be discussed for each type of consumer site; in the discussion the different types of site will be compared with each other.

6.1 Taphonomy

Taphonomy could only be investigated for five assemblages. The taphonomic index is similar, but the index of representativeness varies, with the assemblage from Nijmegen-Canisiuscollege being more representative than the other four (table E6.1). The average bone weight varies from 12 to 44 g.

6.2 Military sites

Despite the strong military presence along the river Rhine, there is a scarcity of animal bone data for military sites when compared to rural sites. In Nijmegen, we have data for the Augustan camp, an early *castellum* (Nijmegen-Trajanusplein), the Early Roman military camp on the Kops Plateau, the Flavian legionary fortress or *castra* on the Hunerberg, and the Late Roman *castellum* on the Valkhof. The only other *castellum* in the research area for which animal bones have been analysed is Meinerswijk. The animal bone assemblage from Meinerswijk dates to A.D. 10-250, which means that no distinction can be made between the Early and Middle Roman periods. Two 1st-century watchtowers have been excavated in Utrecht-Leidsche Rijn. The site Wijk bij Duurstede-De Geer shows evidence for military occupation in the second part of the Middle Roman period. The zooarchaeological data will of course be compared with those from the rural and urban sites, but there are also research questions which relate only to the military sites. The main one is whether there was a different food supply for different types of military site (i.e. *castra*, *castellum*, watchtower).

Where it was possible to identify fragments positively as either sheep or goat, sheep are much more common than goats (table 6.1).[595]

	n sheep	n goat	total	% sheep	% goat
military	9	3	12	75	25
urban/military	13	1	14	93	7
urban	24	7	31	77	23
temples	59	1	60	98	2
total	**105**	**12**	**117**	**90**	**10**

Table 6.1. Numbers of fragments identified as sheep or goat per site category.

6.2.1.1 Species proportions for the four main domesticates per period

Five assemblages from military sites date to the Early Roman period. They show variability in species proportions (fig. 6.1; table E6.3). The two assemblages from the Augustan camp in Nijmegen have very high percentages of pig. The three other assemblages are characterised by a high proportion of cattle. Nijmegen-Trajanusplein has a relatively high proportion of pig, although this is much lower than that for the Augustan camp. In Nijmegen-Kops Plateau the proportion of horse is relatively high, especially in comparison with the other sites. Utrecht-LR31 has a relatively high pro-

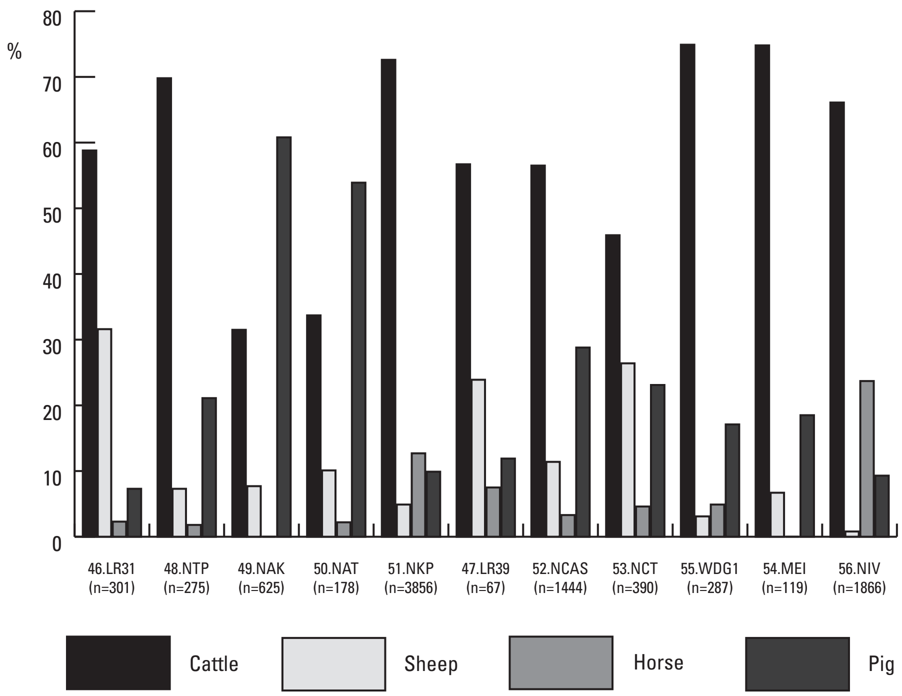

Fig. 6.1. Proportions for the four main domesticates for military assemblages, based on the number of fragments, per assemblage.

595 See table E6.2 for determinations of sheep and goat per site.

portion of sheep. Four assemblages date to the Middle Roman period. Utrecht-LR39 and the two assemblages from Nijmegen-Castra are contemporary; both sites date to the Flavian period. Like the other watchtower in Leidsche Rijn, Utrecht-LR39 has a relatively high proportion of sheep. A high proportion of sheep is also found in the smaller assemblage from the *castra*, but not in the larger one. The *castra* in Nijmegen shows relatively high proportions of pig. Wijk bij Duurstede-De Geer 1 has a high percentage of cattle, low percentages of sheep and horse, and a proportion of pig that is intermediate between the other Middle Roman assemblages. The animal bone assemblage from Meinerswijk shows a high proportion of pig, a low proportion of sheep and no horses at all. In the Late Roman *castellum* on the Valkhof in Nijmegen, sheep is nearly absent, while the high proportion of horse is striking.

6.2.1.2 Nijmegen-Kops Plateau: different zones

The animal bones from Nijmegen-Kops Plateau were collected from three different locations: inside the fort, from a zone of defensive ditches surrounding the fort, and outside the fort. The species proportions for the three zones show some differences (fig. 6.2). The assemblage from inside the fort is dominated by cattle, with only a few percent each for the other three species. The animal bones from the ditch zone have a lower proportion of cattle. All the other species are better represented than inside the fort, but the difference is greatest for pig. The area outside the fort has a relatively low proportion of cattle of 52 % and a high proportion of horse: 37 %. The proportion of sheep is very low, and that for pig is intermediate between the fort and the ditch zone. The different results for the different locations can perhaps be explained by the difference in troops, with auxiliary (cavalry) troops being stationed outside the fort.[596] The horse bones would then be the remains of natural fatalities buried near the camp.

6.2.1.3 Wild mammals

Wild mammals are found in eight of the eleven military assemblages, with percentages ranging from 0.6 to 5.3 % (table E6.4). The total percentage for military sites is 1.6 %. Red deer dominates the wild mammals, with roe deer in second and hare in third place (table 6.2). Apart from badger, fur animals are absent, which suggests that game was hunted primarily for food.

	NAK	NAT	NKP[597]	NCAS	NCT	MEI	WDG1	NIV	total
wild boar							1	8	**9**
red deer		1	25	27		2	2	33	**90**
roe deer	6	9		5	1				**21**
elk								2	**2**
aurochs					1?		1	6	**8**
hare	10			1	4				**15**
badger							1		**1**

Table 6.2. Number of fragments per species of wild mammal for military sites.

6.2.1.4 Chicken and seashells

Chicken was present in six of the eleven military assemblages. The percentage of chicken fragments ranges from 0.4 to nearly 16 % (table E6.5).

[596] Whittaker 2002, 137.

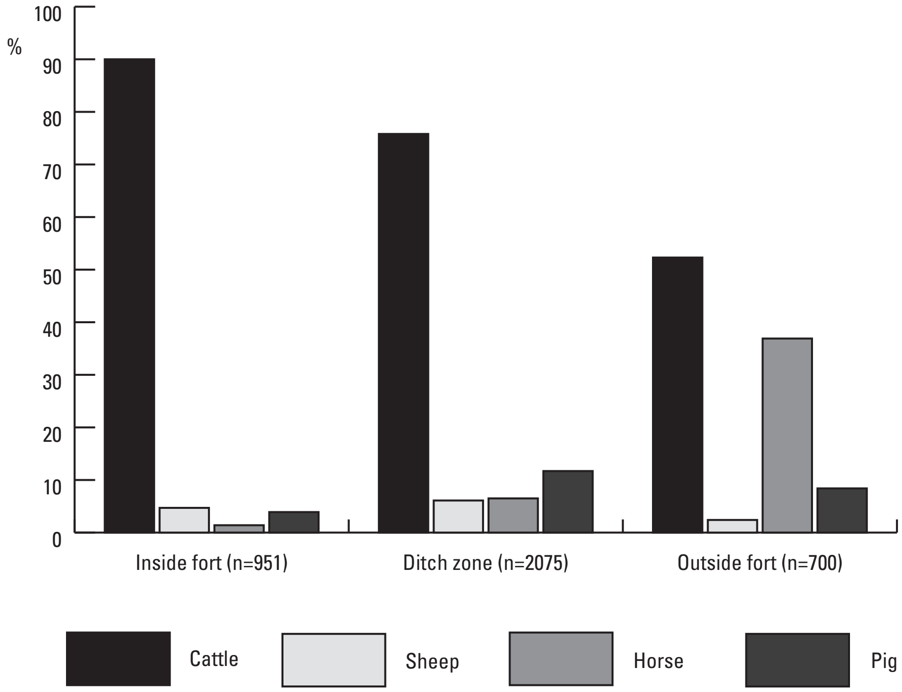

Fig. 6.2. Proportions for the four main domesticates for the different zones in Nijmegen-Kops Plateau, based on the number of fragments (excluding horse skeletons).

Seashells are present in four military sites. The proportion of shells is especially high for the two sites in Utrecht-Leidsche Rijn at 20 and 32 % (table E6.6), while the other assemblages have proportions around or lower than 1 %. Oysters (*Ostrea edulis*) were found in Nijmegen-Castra and Meinerswijk, a cut trough shell (*Spisula subtruncata*) in the smaller assemblage from the *castra*, and the seashells found in Utrecht-LR31 and Utrecht-LR39 consist of mussels (*Mytilus edulis*) and periwinkles (*Littorina littorea*).

6.2.1.5 Wild birds and fish

Remains of wild birds were present in seven of the ten military assemblages for which this could be established (table E6.7). A total of 170 fragments was identified to species or family. Ducks (mallard *Anas platyrhynchos*, teal/garganey *Anas crecca/querquedula* and wigeon *Anas penelope*) and geese (greylag goose *Anser anser*) were both found in five assemblages. Other species present are rook (*Corvus frugilegus*) and pigeon (*Columba* sp.).

Fish remains were present in five of the ten military assemblages for which this could be established (table E6.8). A total of 717 fragments was identified, nearly all from Utrecht-LR31. Pike (*Esox lucius*) and perch (*Perca fluviatilis*) were found in three assemblages, common roach (*Rutilus rutilus*) and white or silver bream (*Abramis bjoerkna*) in two assemblages, and Atlantic salmon (*Salmo salar*), common bream (*Abramis brama*), European eel (*Anguilla anguilla*), houting (*Coregonus oxyrinchus*), Atlantic horse mackerel (*Trachurus trachurus*) and barracuda (*Sphyraena* sp.) in one assemblage. These last two species are interesting because they live only in the sea, and must therefore have been transported inland. Furthermore, the barracuda, found in Nijmegen-Valkhof, is an exotic species.

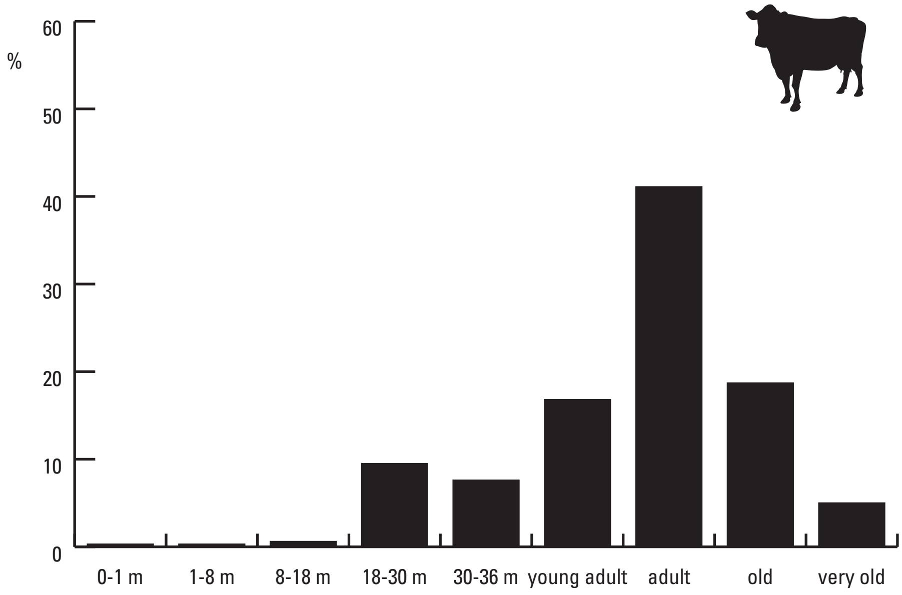

Fig. 6.3. Mortality profile for cattle for Nijmegen-Kops Plateau, based on mandibular tooth eruption and wear (percentages out of the total number of aged mandibles, n=158).

6.2.2 Exploitation of livestock

Data on age and sex of slaughtered animals from consumer sites provide indirect information on animal husbandry strategies in the rural sites that supplied livestock. They also indicate who determined supply: if farmers decided what animals to send to market, then the expectation is that they would choose animals that they could spare, secondary to their own subsistence production. If consumers determined supply, then we can expect to find mostly prime-meat animals. Finally, the presence of neonate animals can indicate that livestock was kept in consumer sites.

6.2.2.1 Sex determinations

For Wijk bij Duurstede-De Geer, two male cattle and one cow were recorded, as well as four boars and two sows. At Nijmegen-Kops Plateau, boars are more common than sows (11 to 2).

6.2.2.2 Cattle: mandibular tooth eruption and wear

For the Early Roman period, the only military site for which age data for mandibles are available is Nijmegen-Kops Plateau. The mandibles were aged according to a different method, but changed into the categories used in this study, so the data can be compared to those from other sites.[598] 41 % of the cattle from Nijmegen-Kops Plateau fall in the age class 'adult' (fig. 6.3). Smaller peaks are visible in the categories 'young adult' and 'old'. For the Middle Roman period, data are available for Wijk bij Duurstede-De Geer 1. Of the ten aged mandibles, 50 % are from old cattle (fig. E6.1). One mandible is from a young calf, which suggests that cattle may have been raised at the site. The remaining mandibles are from animals that were at a prime age for meat.

[597] Only red deer was specifically mentioned by Whittaker, but other species may have been present.

[598] See paragraph 4.3.

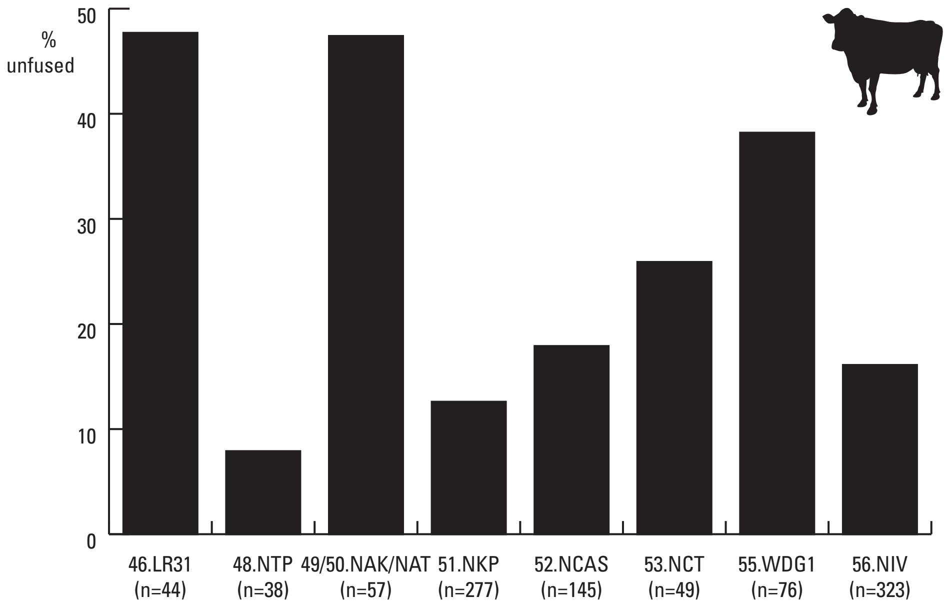

Fig. 6.4. Percentage of unfused epiphyses for cattle from military assemblages.

6.2.2.3 Cattle: epiphyseal fusion

For the Early Roman period, epiphyseal fusion data are available for five assemblages. The two assemblages from the Augustan camp in Nijmegen have been combined to increase the sample size. The proportions of unfused epiphyses for Nijmegen-Trajanusplein and Nijmegen-Kops Plateau are low, while the proportions are much higher for the Augustan camp and Utrecht-LR31 (fig. 6.4). Mortality profiles also show a clear difference between the Augustan camp and Nijmegen-Kops Plateau: in the latter site the majority of cattle consumed were adult (confirming the mandibular data), while in the Augustan camp more young cattle were slaughtered (fig. 6.5). The two assemblages from the Middle Roman *castra* in Nijmegen have proportions of unfused epiphyses that are slightly higher than that for the Early Roman military site Nijmegen-Kops Plateau (fig. 6.4). The combined fusion data for the two assemblages from the *castra* allow a more detailed analysis: 67 % of cattle were older than four years and most of the non-adult cattle were killed between two and four years (fig. 6.5). The proportion of unfused epiphyses at Wijk bij Duurstede-De Geer 1 is much higher than those for the *castra* in Nijmegen (fig. 6.4). The mortality profile shows that slaughter occurred in the first, third and fourth year of life, with 45 % of cattle reaching an adult age (fig. 6.5). This is similar to the mandibular data. Although the number of epiphyses from Meinerswijk was too low to include them, the data fit better with those from the *castra* than with Wijk bij Duurstede-De Geer 1. The proportion of unfused epiphyses at Late Roman Nijmegen-Valkhof is 16 %. Very little slaughter occurred in the first three years, 20 % is killed in the fourth year, and 70 % reach adulthood (fig. 6.5).

6.2.2.4 Sheep/goat

In Nijmegen-Kops Plateau, 30 % of sheep/goat epiphyses are unfused, and 47 % in Nijmegen-Castra. Combined data for nine assemblages give a proportion of 40 %. A sheep mandible from Wijk bij Duurstede-De Geer 1 is from a lamb younger than two months, which suggests that sheep were kept on this site.

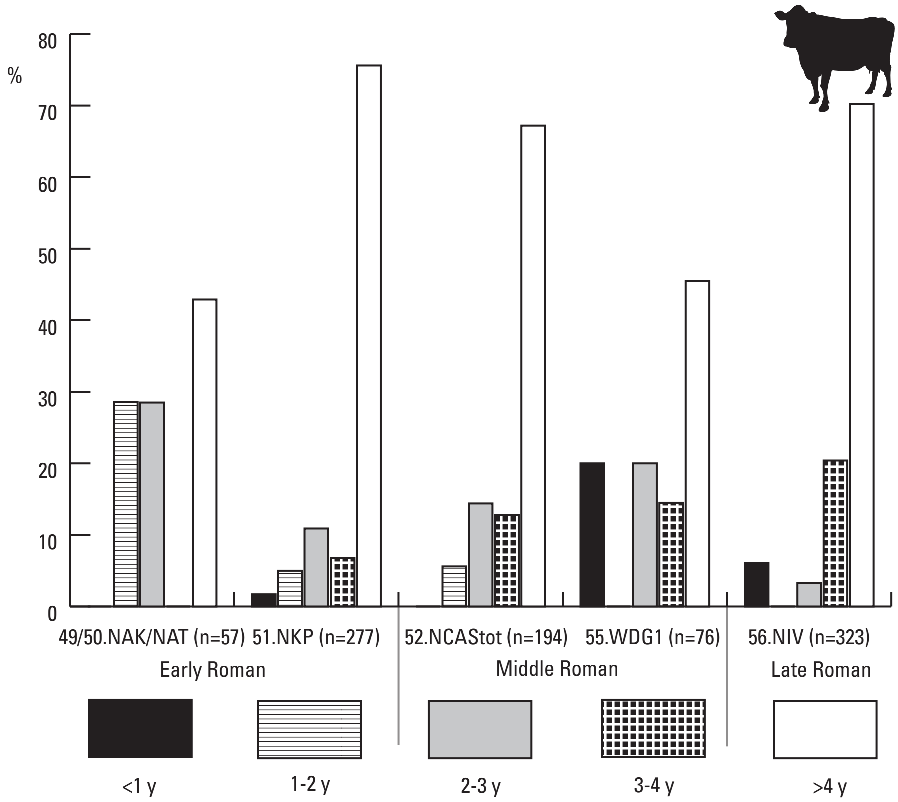

Fig. 6.5. Mortality profiles for cattle from military assemblages, based on epiphyseal fusion.

6.2.2.5 Horse

The proportion of unfused epiphyses is 5 % for Early Roman Nijmegen-Kops Plateau and 16 % for Late Roman Nijmegen-Valkhof. Data from six military sites from all periods were combined and gave a proportion of unfused epiphyses of 13.5 %.

6.2.2.6 Pig

The proportion of unfused epiphyses is 63 % for the Augustan camp, 47.5 % for Early Roman Nijmegen-Kops Plateau, 69.5 % for Middle Roman Nijmegen-Castra and 44 % for Late Roman Nijmegen-Valkhof. Combined data for all military assemblages give a proportion of 60 %. The two assemblages from the Augustan camp have been combined for a more detailed analysis. 63 % of pigs were killed between 1 and 2.5 years (fig. E6.2). The number of epiphyses from Nijmegen-Castra was also high enough to study mortality in more detail. 34 % of pigs are killed in their first year, 34 % again between 1 and 2.5 years, and 26 % between 2.5 and 3.5 years (fig. E6.2). Although the data set from Nijmegen-Kops Plateau does not reach the minimum number of 75 epiphyses, it does suggest that no pigs were killed in the first year.[599]

[599] Of the early-fusing epiphyses, 0 out of 19 were unfused.

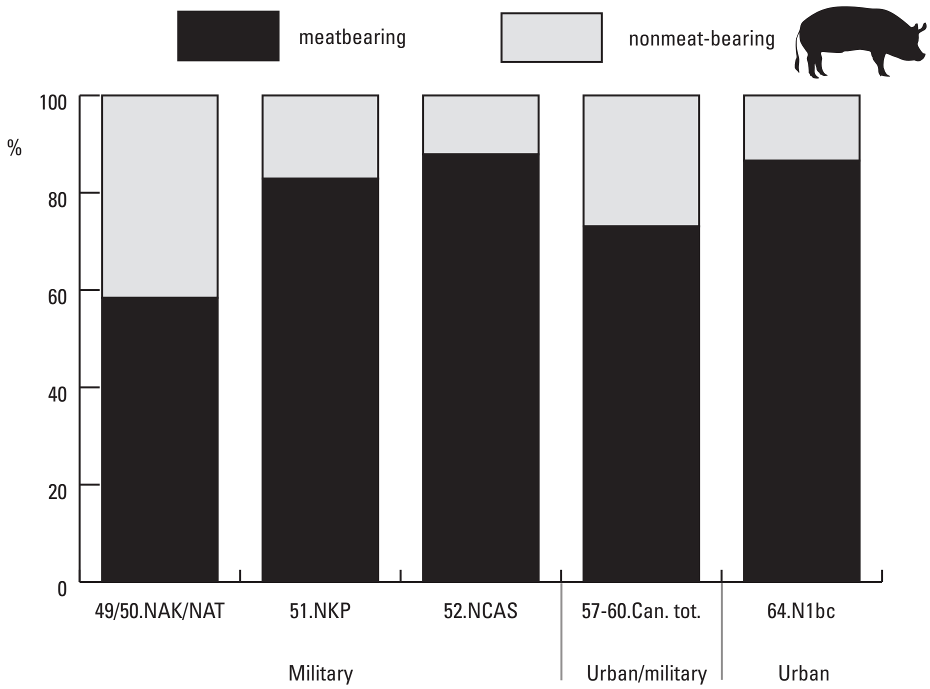

Fig. 6.6. Ratio of meat-bearing to nonmeat-bearing limb bones for pigs from military, urban/military and urban assemblages.

6.2.3 Skeletal element distribution

6.2.3.1 Representation of cattle body parts
Figure E6.3 shows the proportions for the different body parts of cattle. Nijmegen-Kops Plateau is striking because of a very high percentage of head+neck fragments, and few lower limb fragments and phalanges. The percentage of phalanges is also low in Nijmegen-Valkhof. In Utrecht-LR31, percentages for both upper limbs are high.

6.2.3.2 Meat-bearing versus nonmeat-bearing limb bones
The ratio of meatbearing to nonmeat-bearing limb bones of cattle was analysed for seven assemblages.[600] The proportion of meatbearing bones varies from 59 to 78.5 % (fig. E6.4). The proportion of meatbearing bones for sheep in Nijmegen-Castra is 65 %. For pig, the proportion of meatbearing bones in the Augustan camp in Nijmegen (combined assemblages) is relatively low with 58 % (fig. 6.6). In the two later military sites, it is much higher: 83 and 88 %.

6.2.4 Butchery

The percentage of butchery marks on cattle bones for four military assemblages varies from 5 to 26.5 % (fig. 6.7). The ratio of chop to cut marks could be calculated for Koopman's assemblage from the Augustan camp and Wijk bij Duurstede-De Geer 1 (fig. 6.8). In Wijk bij Duurstede-De Geer 1, 53 % of the chop marks are superficial, while 47 % are chops through bones. Figure 6.9 shows butchery

[600] The two assemblages from the Augustan camp were combined to reach a larger sample size.

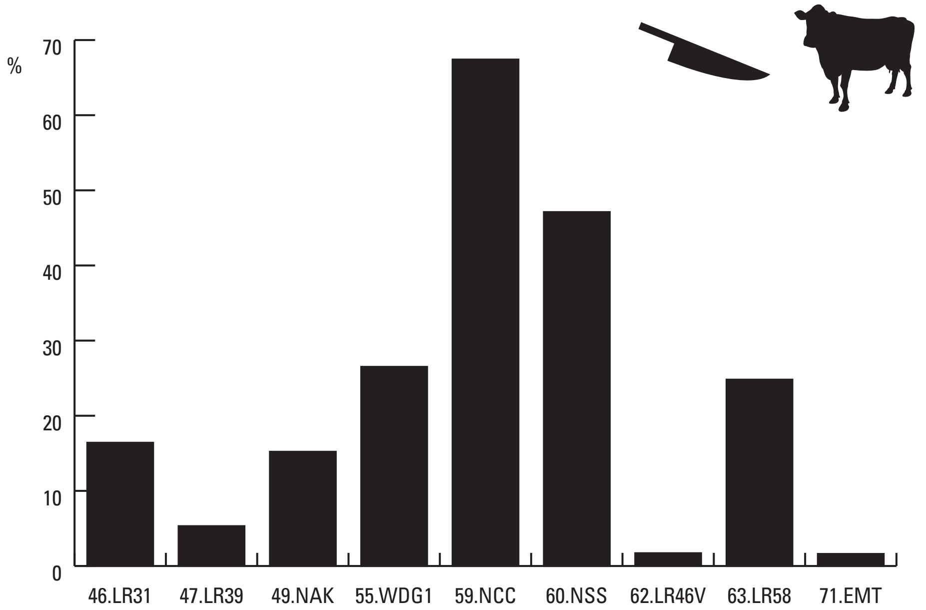

Fig. 6.7. Percentage of butchery marks for cattle for assemblages from consumer sites (out of the total number of fragments).

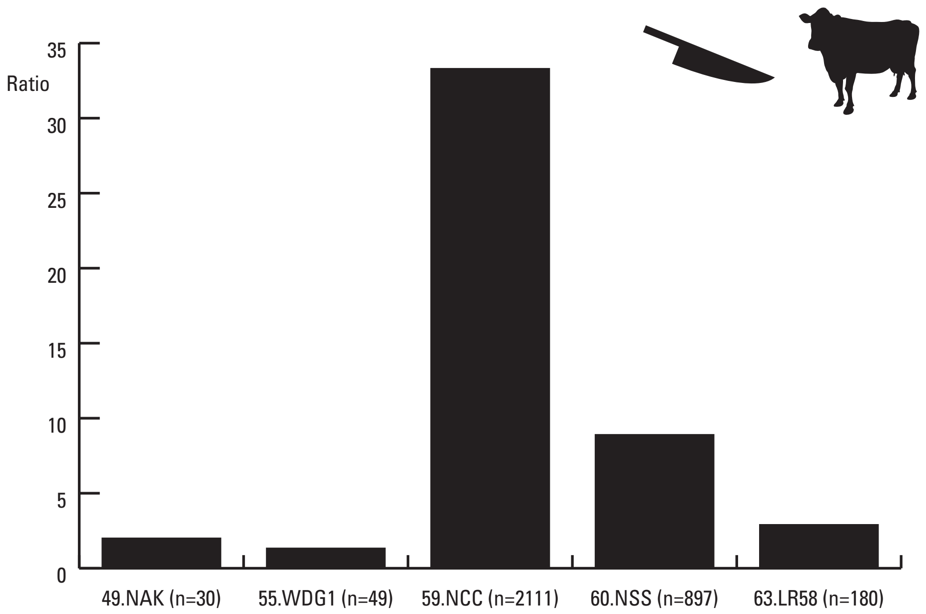

Fig. 6.8. Chop-cut index for cattle from assemblages from military and urban/military sites (n is the number of butchery marks).

marks on cattle bones from Wijk bij Duurstede-De Geer 1. These butchery marks indicate that the head was separated from the spinal column, and the mandible removed from the skull. There is also evidence for the segmenting of the spinal column and/or removing the ribs and for the chopping of ribs into smaller portions and removing meat from the ribs. Some of the cut marks on the shoulder-blade are typical for smoked shoulders. The chopping off of parts of the articulations of the long bones was common. Cut marks on the distal part of the first phalanx may be associated with skinning. Since the number of horse numbers is low in most military sites, percentages of butchery marks could not be calculated, even when information on butchery was available.

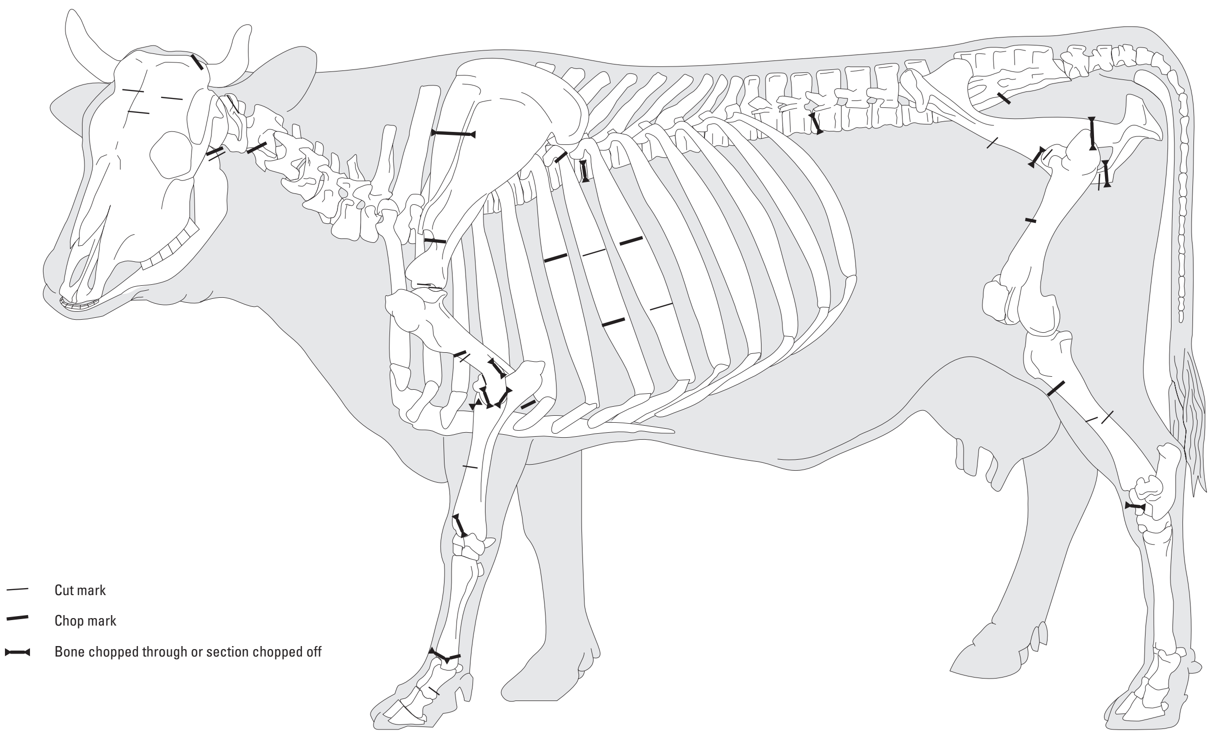

Fig. 6.9. Butchery marks on cattle bones from Wijk bij Duurstede-De Geer 1 (Template: archeozoo.org).

6.2.5 Biometrical analysis

6.2.5.1 Withers height

Only withers heights for cattle could be traced over time throughout the Roman period. For sheep, no withers heights are available for the Late Roman period, and for horse, the samples for the Early and Middle Roman periods are small. For pig, no withers heights were available at all. The mean withers height for cattle shows a slight increase from the Early to the Middle Roman period, and a more significant increase in the Late Roman period (table 6.3). Withers height for sheep increases in the Middle Roman period, but the sample is small (table 6.3). Table 6.3 also shows the mean and range for withers heights for horses, but the samples are too small to draw any conclusions.

	mean (cm)	n	range (cm)
cattle			
Early Roman period[601]	115	14	105 – 125
Middle Roman period[602]	116	9	103 – 132
Late Roman period[603]	127	54	113 – 143
sheep			
Early Roman period[604]	61	8	56 – 68
Middle Roman period[605]	63	6	60 – 67
horse			
Early Roman period[606]	136	5	121 – 145
Middle Roman period[607]	132	2	129 – 135
Late Roman period[608]	140	32	132 – 150

Table 6.3. Reconstructed withers height for cattle, sheep and horses from military sites.

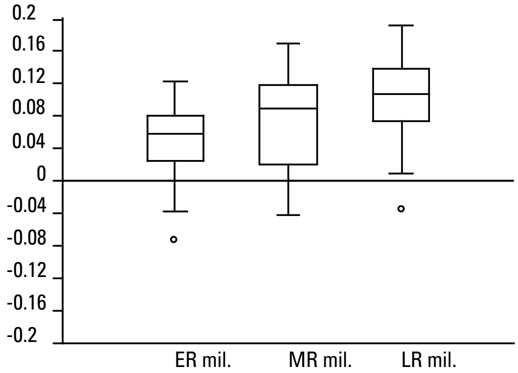

Fig. 6.10. LSI for width measurements for cattle from military assemblages, per period.

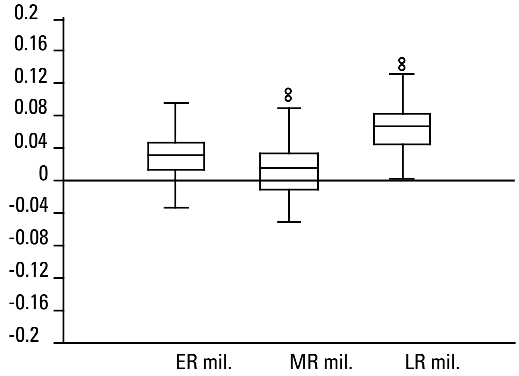

Fig. 6.11. LSI for length measurements for cattle from military assemblages, per period.

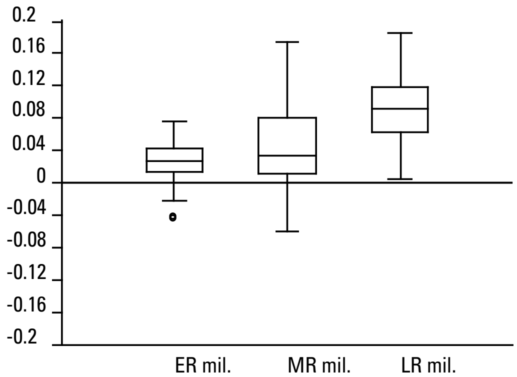

Fig. 6.12. LSI for depth measurements for cattle from military assemblages, per period.

6.2.5.2 Log size index for cattle

Measurements from five military sites were used in this analysis: Nijmegen-Trajanusplein, Nijmegen-Kops Plateau, Nijmegen-Castra, Wijk bij Duurstede-De Geer 1 and Nijmegen-Valkhof. Data from the military sites were pooled per period to see if any changes occurred over time. From the Early to the Middle Roman period, only width measurements show a statistically significant increase (figs. 6.10-12; table E6.9). From the Middle to the Late Roman period, a change is visible in all three dimensions, which is statistically highly significant.

LSI data for all measurements have been combined per site. This shows that cattle from Nijmegen-Trajanusplein, Nijmegen-Kops Plateau and Nijmegen-Castra are of a similar size (fig. E6.5; table E6.10). The cattle from Wijk bij Duurstede-De Geer have a much larger mean, but a similar range, while those from Nijmegen-Valkhof have both a larger mean and range.

601 Nijmegen-Kops Plateau: 13 withers heights; Nijmegen-Trajanusplein: 1 withers height.

602 Nijmegen-Castra: 6 withers heights; Wijk bij Duurstede-De Geer: 3 withers heights.

603 All from Nijmegen-Valkhof.

604 All from Nijmegen-Kops Plateau.

605 All from the castra in Nijm*egen*.

606 All from Nijmegen-Kops Plateau.

607 Nijmegen-Castra: 1 withers height; Wijk bij Duurstede-De Geer: 1 withers height.

608 All from Nijmegen-Valkhof.

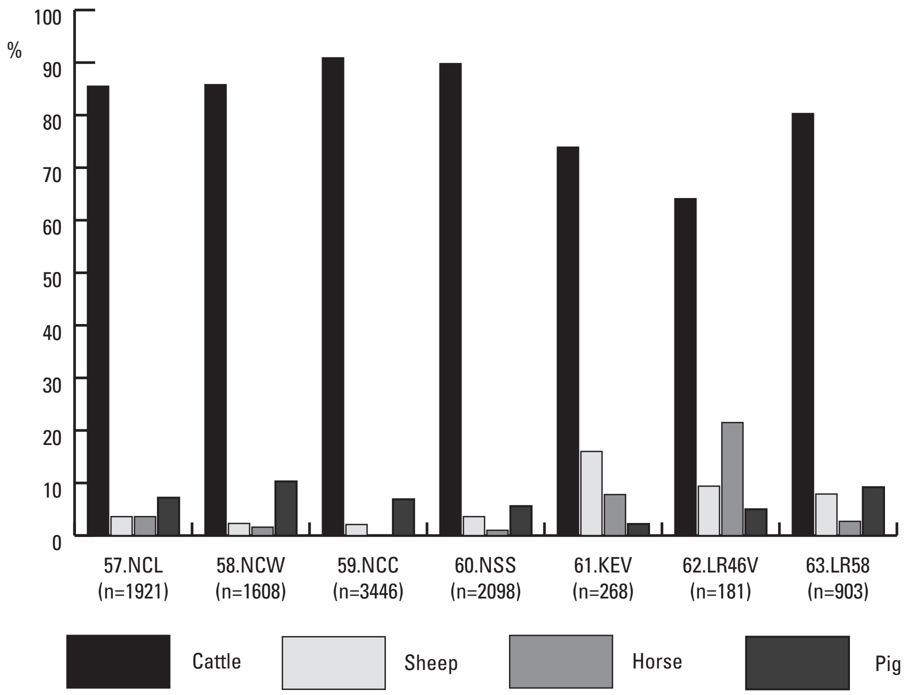

Fig. 6.13. Proportions for the four main domesticates for urban/military assemblages, based on the number of fragments, per assemblage.

6.2.6 archaeobotany

Archaeobotanical information was available for two military sites: the Augustan camp in Nijmegen and Utrecht-LR31. The cereals emmer wheat, barley and oat are present in both sites. In addition, millet was found in the Augustan camp and possibly spelt in Utrecht-LR31. Lentil was probably present in the Augustan camp and must have been imported, since it is not of local origin.[609] Olive is another imported product. Walnut, which was found in Utrecht-LR31, was probably also imported. Collected fruits and nuts are represented by hazelnut in the Augustan camp and elderberry in Utrecht-LR31.

6.3 urban/military sites

The category of urban/military sites includes the *canabae legionis* in Nijmegen, from which four animal bone assemblages could be included. They all date roughly to the period A.D. 70-120. The three other assemblages are from *vici*. Utrecht-LR46V and Utrecht-LR58 are part of the same *vicus*, located next to *castellum* De Meern. The first assemblage dates to the Middle Roman period, while the assemblage from Utrecht-LR58 probably dates mostly to the Flavian period.[610]

[609] Personal communication Laura Kooistra.

[610] Some of the animal remains from Utrecht-LR58 were dated to more precise phases, but the majority was not. Although the chronology covers a period from c. A.D. 40 to the 2nd century and perhaps later, the Flavian period was best represented among the phased animal bones. Esser 2012.

6.3.1.1 Species proportions for the four main domesticates

All assemblages from the *canabae* are dominated by cattle, with none of the other species reaching percentages over 10 % (fig. 6.13; table E6.11). In Kesteren-Vicus, cattle has a high proportion of 74 %; the only other species that is significant is sheep with 16 %. Utrecht-LR46V and Utrecht-LR58 show a difference in species proportions. The proportion of horse is relatively high in Utrecht-LR46V. Perhaps this can be explained by the peripheral location of the excavation, on the edge of the *vicus*. The proportion of cattle is lower as a result of the higher proportion of horse. The assemblage from Utrecht-LR58 is dominated by cattle, with percentages for all three other species lower than 10 %.

6.3.1.2 Wild mammals

Wild mammals are present in five assemblages; they are missing in Kesteren-Vicus and Utrecht-LR46V. The proportion of wild mammals ranges from 0.2 to 0.8, with an average of 0.4 % (table E6.4). Red deer is the most common wild mammal (table 6.4). As was already noted for the military sites, wild mammals seem to have been hunted for meat and not fur.

	NCL	NCW	NCC	NSS	LR58	total
wild boar			3			**3**
red deer	14	3	2	9	6	**34**
roe deer			2	2	1	**5**
aurochs	1		1			**2**
hare			1			**1**

Table 6.4. Number of fragments per species of wild mammal for urban/military sites.

6.3.1.3 Chicken and seashells

Chicken was present in all assemblages from the *canabae*, as well as in Utrecht-LR58 (table E6.5). The percentage of chicken bones ranges from 0.3 to 0.7 %. Seashells were only found in three assemblages (table E6.6): mussels in the *canabae*, two oysters and a whelk (*Buccinum undatum*) in Kesteren-Vicus and oysters in Utrecht-LR58.

6.3.1.4 Wild birds and fish

Remains from wild birds were found in five of the six assemblages from urban/military sites for which the presence could be established (table E6.7), with a total of 84 fragments identified to species or family. Geese (greylag or domestic goose *Anser anser/domesticus*, greater white-fronted goose *Anser albifrons*, bean goose *Anser fabalis*, brent goose *Branta bernicla* and barnacle goose *Branta leucopsis*) are present in all five assemblages and ducks in four (mallard *Anas platyrhynchos*, pintail *Anas acuta*, teal *Anas crecca* and common pochard *Aythya ferina*), together accounting for 71 of the fragments. Seven other species were present.[611] Apart from bird remains from the assemblages included in this study, a pot with preserved song thrush breasts, imported from the Ardennes, was found in Nijmegen-Kops Plateau.[612]

Fish remains were present in four assemblages (table E6.8). Of the 1615 fragments, most come from Nijmegen-Canisiuscollege. Remains of cyprinids (not further identifiable) dominate this assemblage. Tench is the only species that occurs in three assemblages, while pike, sturgeon (*Acipenser sturio*) and

611 Bewick's swan (*Cygnus bewickii*), golden plover (*Pluvialis apricaria*), woodcock (*Scolopax rusticola*), carrion crow (*Corvus corone*), grey heron (*Ardea cinerea*), short-eared owl (*Aseo flammeus*) and finch (*Fringillidae*).

612 Lauwerier 1993.

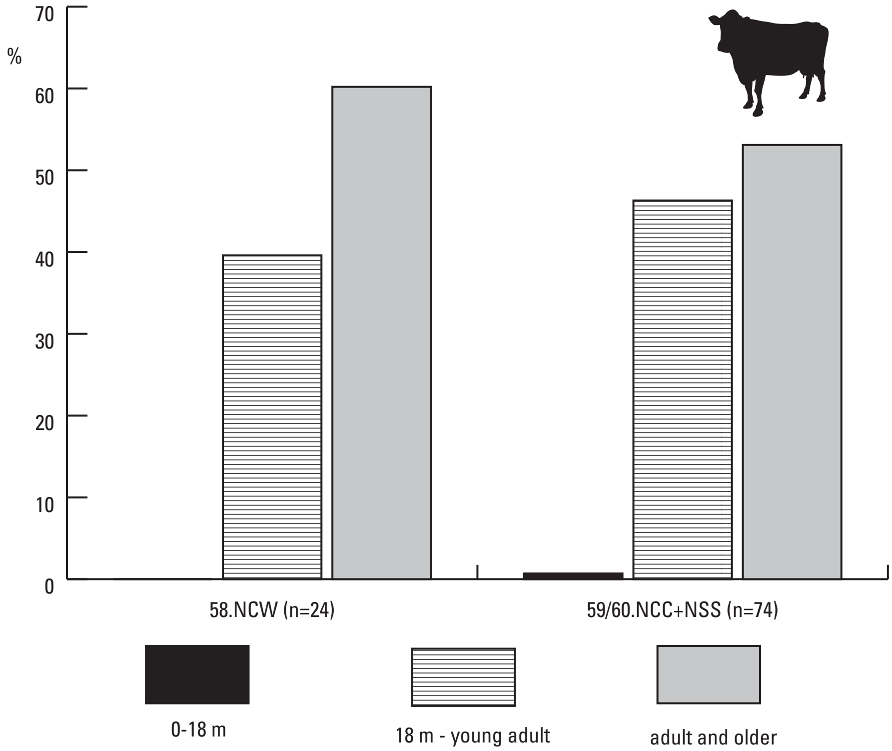

Fig. 6.14. Mortality profile for cattle for three assemblages from the *canabae* in Nijmegen, based on mandibular tooth eruption and wear (percentages out of the total number of aged mandibles).

bream are found in two assemblages. Of the other eight species, the only noteworthy one is the asp (*Aspius aspius*), a species which is not found in the Netherlands today but may have been native in the Roman period.[613] Two finds from Nijmegen-Kops Plateau (not part of the assemblage included in this study) provide evidence for the trade in fish and fish products. A concentration of bones from chub mackerel (*Scomber japonicus*), which is not native to the Atlantic or the North Sea, was found in a latrine, and three complete specimens of the same species were found in a pot, probably salted.[614]

A further assemblage from Nijmegen-Canisiuscollege was not included in this study because of the lack of quantifiable data, but contains both bird and fish remains.[615] This assemblage includes some species not encountered in the other urban/military assemblages.[616]

6.3.2 Exploitation of livestock

6.3.2.1 Sex determinations

All the available sex determinations are for the *canabae*. For cattle, one male and one female were recorded. For sheep or goat, four males and one female were present, while the only sex determinations for horse are of two stallions or geldings. Seventeen boars and 30 sows were recorded for pig.

613 Personal communication Frits Laarman. The other seven species are houting, eel, silver bream, barbel, common roach, perch and salmon.

614 Lauwerier 1993; 2009, 162.

615 Hoek/Brinkhuizen 1990.

616 Birds: crane, white-tailed eagle (*Haliaeetus albicilla*), thrush and starling. Fish: allis shad, wels catfish (*Siluris glanis*) and ide or orfe (*Leuciscus idus*).

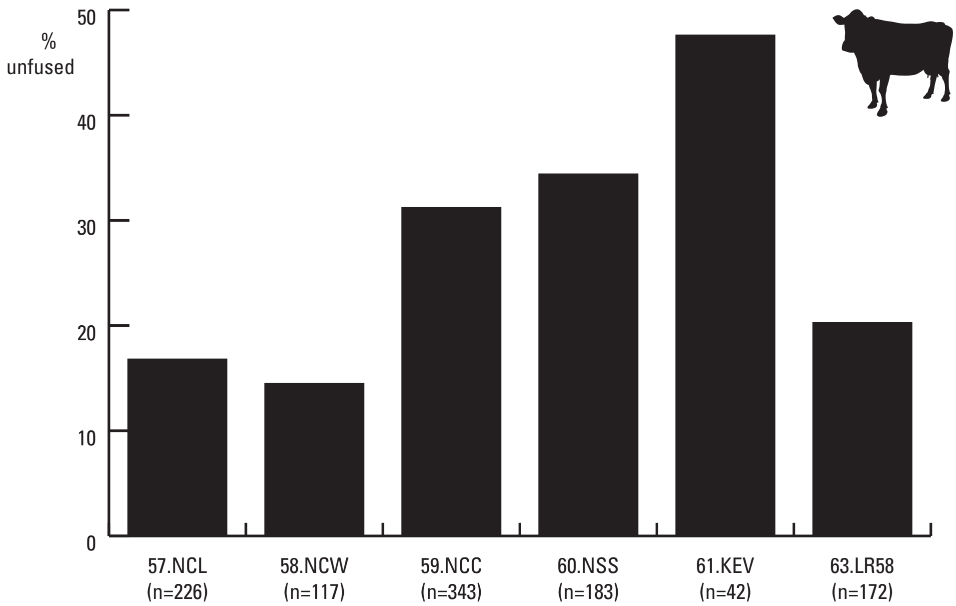

Fig. 6.15. Percentage of unfused epiphyses for cattle from urban/military assemblages.

6.3.2.2 Cattle: mandibular tooth eruption and wear

Since the mandibular data from Nijmegen-Canisiuscollege and Nijmegen-Schippersinternaat are from the same site and give similar results, they have been combined. Whittaker`s assemblage from the *canabae* is somewhat different, so has not been added to the other two assemblages. The data from Canisiuscollege/Schippersinternaat show a slaughter peak of 26 % between 18 and 30 months, while Whittaker`s data show less slaughter in this age category (fig. E6.6). His data show a peak in the `adult` category, and a smaller one in the `young adult` one. Although there seems to be a difference in slaughter ages, this could partly be related to the different methods used. When the data are grouped into broader categories, the results are very similar, with no slaughter of cattle younger than 18 months, 40-46 % killed at a prime age for meat, and 53-60 % adult and older animals (fig. 6.14). The two assemblages from the *vicus* in Utrecht-Leidsche Rijn show differences in slaughter peaks: in Utrecht-LR46V a slaughter peak is found for the age category 'young adult', while Utrecht-LR58 shows a clear slaughter peak in the category 18-30 months (fig. E6.7).[617]

6.3.2.3 Cattle: epiphyseal fusion

The proportion of unfused epiphyses for the assemblages from the *canabae* varies between 14.5 and 34 % (fig. 6.15). The proportion for Utrecht-LR58 falls within this range, while that for Kesteren-Vicus is much higher. All the data from the *canabae* have been combined in the mortality profile. Both the *canabae* and Utrecht-LR58 show practically no slaughter of cattle younger than two years (fig. 6.16), which was also seen in the mandibular data. Slaughter in the third and fourth year is similar in Utrecht-LR58. In the *canabae*, fewer cattle are slaughtered in the fourth than in the third year, and nearly half the cattle are adult. The proportion of adults in the mortality profiles based on epiphyseal fusion for the *canabae* and Utrecht-LR58 is roughly similar to that based on tooth eruption and wear.

[617] The difference between the two *vicus* assemblages also disappears when broader age categories are used, but in this case the same ageing methods were used, which means that the difference is not related to a difference in methodology.

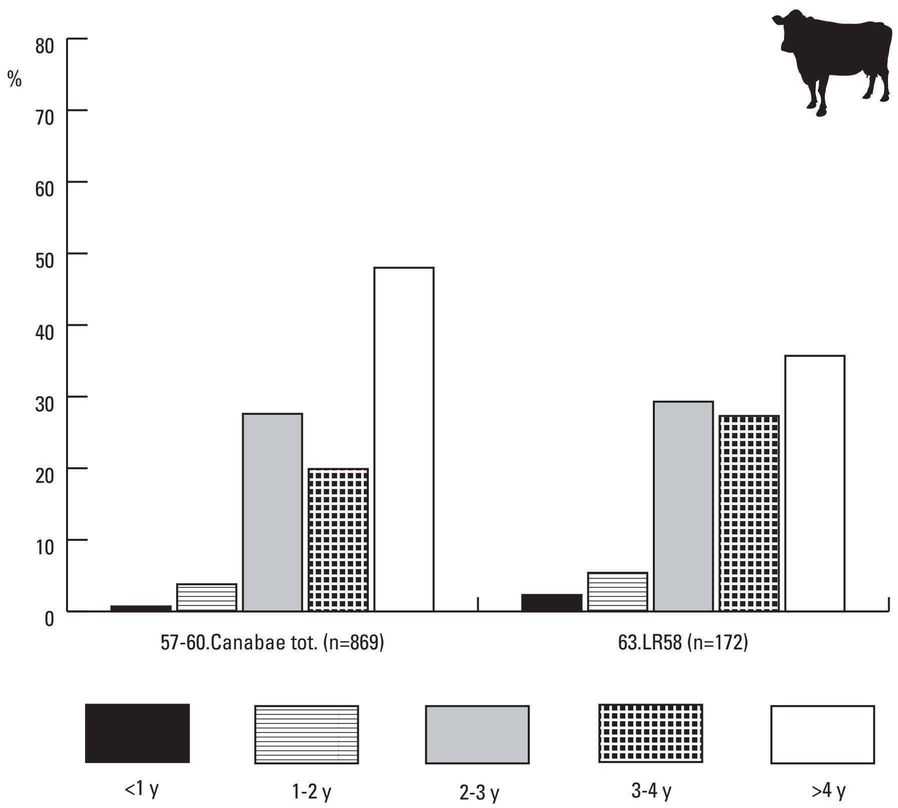

Fig. 6.16. Mortality profiles for cattle from urban/military assemblages, based on epiphyseal fusion.

6.3.2.4 Sheep/goat

Mandibular data from the *canabae* (Nijmegen-Canisiuscollege and Nijmegen-Schippersinternaat) suggest that mainly adult sheep or goats were slaughtered (fig. E6.8). However, the proportion of unfused epiphyses for three assemblages from the *canabae* (Canisiuscollege, Schippersinternaat and data from Lauwerier) is rather high: 43 %.

6.3.2.5 Horse

There are no assemblages with a total number of scored epiphyses for horse over 30. Only fused epiphyses were found in Utrecht-LR46V and the *canabae*, although (partial) skeletons of both adult and non-adult horses were found in Nijmegen-Schippersinternaat. A few unfused epiphyses were present in Utrecht-LR58 and Kesteren-Vicus. Overall, the majority of horses in urban/military sites seem to have been adults.

6.3.2.6 Pig

Mandibular data for the *canabae* (combined for Nijmegen-Canisiuscollege and Nijmegen-Schippersinternaat) show a large slaughter peak between 14 and 21 months, but also significant slaughter between 7 and 14 months (fig. E6.9). The proportion of unfused epiphyses for the *canabae* is 67 %, with the highest slaughter peak occurring in the first year (fig. E6.10).

6.3.3 Skeletal element distribution

6.3.3.1 Representation of cattle body parts
The assemblages from the *canabae* show a great degree of variability (fig. E6.11). The Schippersinternaat assemblage, a dump site, does not show higher proportions of parts that can be regarded as primary slaughter refuse. The assemblages from Kesteren-Vicus and Utrecht-LR58 do not differ markedly from those from the *canabae*.

6.3.3.2 Meat-bearing versus nonmeat-bearing limb bones
The proportion of meat-bearing bones for cattle in four assemblages from the *canabae* varies between 64 and 84.5 %, while it is much lower for Utrecht-LR58 (fig. E6.12). Two pits analysed by Robeerst (Canisiuscollege) contained mostly meat-bearing limb bones from cattle, suggestive of consumption refuse. For sheep and goat, all assemblages from the *canabae* were combined to reach a large enough sample: the percentage of meat-bearing bones is 62 %. Assemblages from the *canabae* were also combined for pig, which resulted in a proportion of meat-bearing bones of 73 % (fig. 6.6).

6.3.3.3 Nijmegen-canabae: specialised processing of meat
The *canabae* have revealed some evidence for the specialised processing of cattle. Lauwerier concluded from the large number of scapulae found in the western *canabae* (mostly in one well and one pit) that this part of the *canabae* was used for processing cattle shoulders. Perforations in the blade of the scapula and other typical butchery marks indicate that these shoulders were smoked.[618] Whittaker also came to the conclusion that scapulae are overrepresented in the *canabae*.[619] Large quantities of skull fragments and mandibles found in the eastern *canabae* were interpreted by Lauwerier as evidence for the production of brawn.[620] During slaughter, mandibles and to a lesser extent skulls were kept separate and processed. The meat from the head was cooked, taken from the bone and mixed with herbs. Lauwerier suggests that the meat products made in the *canabae* were partly intended as food for the *castra*. In the case of the shoulderblades, however, this seems less plausible, as whole hams would have been traded. The shoulderblades are likely to represent not refuse from a smokery, but rather that from an inn or a shop selling small portions of processed meat.

6.3.4 Butchery

The percentage of butchery marks on cattle bones is very low in Utrecht-LR46V, high in Utrecht-LR58 and very high in the two assemblages from the *canabae* (fig. 6.7). The ratio of chop to cut marks was established for three assemblages; it is especially high in Nijmegen-Canisiuscollege (fig. 6.8). In Utrecht-LR58, 74 % of chop marks are superficial, while 26 % chop through bones or chop off part of a bone.

For Utrecht-LR58, Esser recorded butchery marks in detail. This means that we can see the way cattle were butchered (fig. 6.17). Ribs were not identified to species, but butchery indicates removing ribs from the spinal column, chopping ribs into smaller sections and removing the meat. The perforation of the shoulderblade is typical for smoked shoulders. As in Wijk bij Duurstede-De Geer 1, the chopping off of parts of the articulations of long bones, presumably to separate the joints, is common. Cut marks on phalanges indicate skinning.

618 Lauwerier 1988, 61.

619 Whittaker 2002, 219.

620 Lauwerier 1988, 62-64.

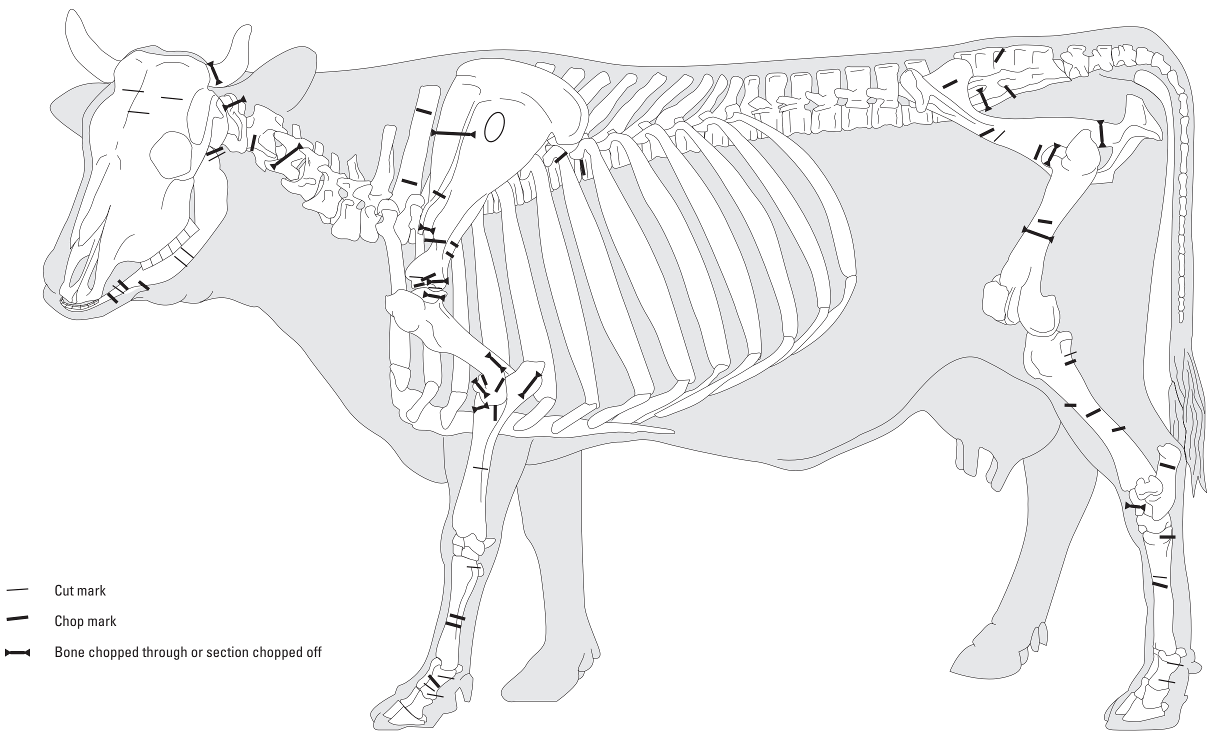

Fig. 6.17. Butchery marks on cattle bones from Utrecht-LR58 (Template: archeozoo.org).

The percentage of butchery marks on horse bones was calculated for the assemblages from the *vicus* in Utrecht-Leidsche Rijn together, where it is 6 %. No butchery marks were present on the horse bones in the assemblage Nijmegen-Schippersinternaat.

6.3.5 BIOMETRICAL ANALYSIS

6.3.5.1 Withers height

Table 6.5 shows the mean and range for withers heights for cattle, sheep and horse from urban/military sites. These results will be compared with those from other consumer sites in paragraph 6.6.4.1.

	mean (cm)	n	range (cm)
cattle[621]	116	11	98 – 142
sheep[622]	64	7	59 – 72
horse[623]	146	9	127 – 163

Table 6.5. Reconstructed withers height for cattle, sheep and horses from urban/military sites. All data are from the Middle Roman period.

621 Nijmegen-Canabae: 9 withers heights (3 NCL, 1 NCW, 2 NCC, 3 NSS); Kesteren-Vicus: 1 withers height; Utrecht-LR58: 1 withers height.

622 Nijmegen-Canabae: 7 withers heights (2 NCL, 1 NCC, 3 NSS, 1 NCT); Utrecht-LR46V: 1 withers height.

623 Nijmegen-Canabae: 5 withers heights (2 NCL, 2 NCC, 1 NSS); Kesteren-Vicus: 1 withers height; Utrecht-LR46V: 2 withers heights; Utrecht-LR58: 1 withers height.

6.3.5.2 Log size index for cattle

Measurements are available for four assemblages from the *canabae* in Nijmegen, Kesteren-Vicus and Utrecht-LR58. Data from the last two sites were pooled and compared with those from the *canabae*. There is no statistical difference between the sites, but the sample size for the sites outside Nijmegen is very small (figs. E6.13-15; table E6.12). In paragraph 6.6.4.3, the data from the *canabae* will be compared with those from the *castra*.

6.3.6 ARCHAEOBOTANY

Archaeobotanical analysis of 40 samples from Nijmegen-Canisiuscollege has resulted in a large variety of plants. The cereals present in this site are emmer, barley, oat, millet, bread wheat and spelt wheat. Three types of pulses were found: Celtic bean, pea and lentil. Herbs introduced in the Roman period but probably grown locally are dill and summer savoury. The category fruits and nuts is especially well-represented, with both wild and cultivated species: dewberry, blackberry, elderberry, sloe, cherry, damson, apple, pear, plum, hazelnut and walnut. Three species are exotic and were certainly imported: fig, olive and grape. Apart from the botanical macro-remains, remains from bread were also present. The botanical samples from Utrecht-LR58 have yielded several species of cereal: emmer wheat, barley, oat, millet, spelt wheat and perhaps also bread wheat. The last two cereals were certainly imported; further evidence for this is provided by two weeds typical for more southern regions: white lace flower (*Orlaya grandiflora*) and common corncockle (*Agrostemma githago*). Hazelnut could be collected locally. Coriander, celery and probably aniseed (cf. *Pimpinella anisum*, attested by pollen) were introduced by the Romans but may have been cultivated locally. In Kesteren-Vicus, the cereals emmer wheat, barley, oat and millet were present. Rape and flax were probably grown for their oil. Two pulses were found: Celtic bean and common vetch.[624] Other cultivated plants found in this site are beet, coriander, opium poppy and dyer's rocket. Hazelnut and elderberry could be collected locally.

6.4 URBAN SITES

The *civitas Batavorum* only really had one town: Nijmegen, also known as *Oppidum Batavorum* (1st century A.D.) or *Ulpia Noviomagus* (after c. A.D. 70). Two assemblages are available for *Oppidum Batavorum*, and another two (subdivided into different phases) for *Ulpia Noviomagus*. A problem that is specific to urban sites is that they are rarely representative for the entire town. Because of the generally large size of towns, excavations usually only cover a small part. Furthermore, activities in towns are often highly specialised and segregated. Rural settlements may also have had activity zones, but are usually excavated to a larger extent, so that the total assemblage gives a more representative view. In urban sites, we can expect to encounter domestic waste (from households, providing evidence for consumption), butchery waste (from specialist butchers, providing evidence for the processing of meat and specialist meat products) and industrial waste (providing evidence for craft activities). Urban assemblages provide a detailed look at certain parts of a town, but may not give an average of the total meat consumption for different species. They are not always easy to interpret or compare with rural assemblages.

[624] It is not certain whether common vetch was eaten by humans; it may have been grown as fodder. Personal communication Laura Kooistra.

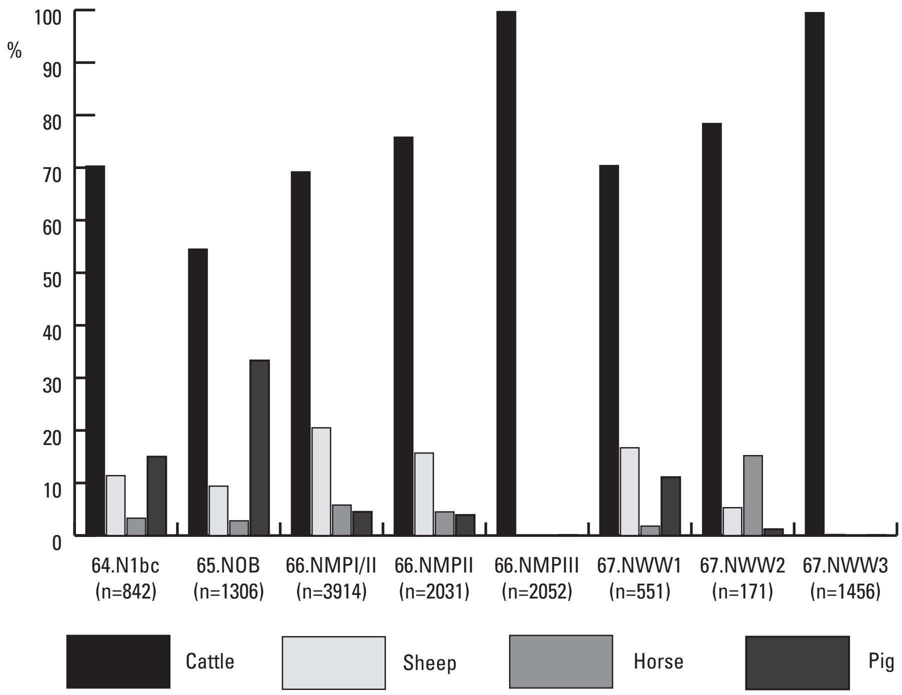

Fig. 6.18. Proportions for the four main domesticates for urban assemblages, based on the number of fragments, per assemblage.

6.4.1 species proportions

6.4.1.1 Species proportions for the four main domesticates per period

The species proportions for the two Early Roman urban assemblages from *Oppidum Batavorum* are similar in that they both show a dominance of cattle, followed by a relatively high percentage of pig (fig. 6.18; table E6.13). Sheep accounts for around 10 %, and horse is found in small proportions. The main difference between the assemblages lies in the percentages of cattle and pig: the assemblage analysed by Lauwerier has a much higher percentage of cattle and a lower percentage of pig than the assemblage analysed by Robeerst. Robeerst was able to divide her material into two phases, which showed an increase in sheep at the expense of pig.[625]

For the Middle Roman period, seven urban assemblages were available. The two sites in *Ulpia Noviomagus* have revealed large numbers of animal bones. The Nijmegen-Maasplein assemblage was divided into three phases. The assemblage with the latest dating is a cattle butchery site, characterised by an extremely high percentage of cattle: 99.7 % (fig. 6.18). The Nijmegen-Weurtseweg assemblage was also divided into three phases. Again, the latest assemblage is a cattle butchery site, in this case with 99.5 % cattle fragments. The two earlier assemblages from Nijmegen-Maasplein are characterised by high proportions of cattle, with sheep as the second species. The earliest assemblage from Nijmegen-Weurtseweg shows similar percentages of cattle and sheep to Nijmegen-Maasplein II, but a higher proportion of pig. In the assemblage Nijmegen-Weurtseweg 2, sheep and pig are insignificant, but horse has a relatively high proportion of 15 %.

[625] Robeerst 2005a, 83.

[626] One in Nijmegen-Oppidum Batavorum and an unknown quantity in Nijmegen 1bc.

6.4.1.2 Wild mammals
Wild mammals are present in all assemblages; proportions vary between 0.2 and 0.8 %, with an average of 0.5 % (table E6.4). Red deer is the most common species (table 6.6). Apart from large game animals, single fragments of a beaver and a cat were found in Nijmegen-Maasplein. It cannot be excluded that the cat is domestic.

	N1bc	NOB	NMP I/II	NMP II	NWW	total
red deer	2	3	19	3	5	**32**
roe deer		3	1	4		**8**
aurochs		2		3		**5**
hare		2				**2**
wild? cat			1			**1**
beaver			1			**1**

Table 6.6. Number of fragments per species of wild mammal for urban sites.

6.4.1.3 Chicken and seashells
Chicken was present in Nijmegen 1bc, Nijmegen-Oppidum Batavorum, Nijmegen-Weurtseweg and Nijmegen-Maasplein I/II and II, with percentages between 0.2 and 3.8 % (table E6.5). Oysters were present in both assemblages from *Oppidum Batavorum*.[626] A fragment of a mussel in Nijmegen 1bc could not be identified to species, and may either be from a freshwater or saltwater mussel. It is not clear whether oysters or other seashells were found in the assemblages Nijmegen-Maasplein and Nijmegen-Weurtseweg.

6.4.1.4 Wild birds and fish
Remains from wild birds were found in all three urban sites for which the presence or absence could be established (table E6.7). Geese (greylag/domestic goose and bean goose) and ducks (mallard) account for 92 of the 102 fragments. Other species are woodcock, white-tailed eagle, raven (*Corvus corax*) and pigeon. Fish remains were present in two of the three urban sites (table E6.8); seven species were recognised.[627]

6.4.2 Exploitation of livestock

6.4.2.1 Sex determinations
The only sex determinations available for the urban assemblages are from Nijmegen-Weurtseweg, where two boars and one sow were recorded.

6.4.2.2 Cattle: mandibular tooth eruption and wear
For the Early Roman period, no age data based on mandibles are available for urban sites. For the Middle Roman period, mandibular data are available for Nijmegen-Weurtseweg. The proportion of adult or older cattle is very high (fig. E6.16). Quadratic crown height data from Nijmegen-Maasplein were converted to three broad categories. Over 50 % of cattle fall into the category 'older than four years', 38 % were killed between two and four years, and only 11 % in the first two years (fig. E6.17).

[627] Pike, tench, allis/twaite shad (*Alosa alosa/fallax*), salmon, wels catfish, sturgeon and ide or orfe.

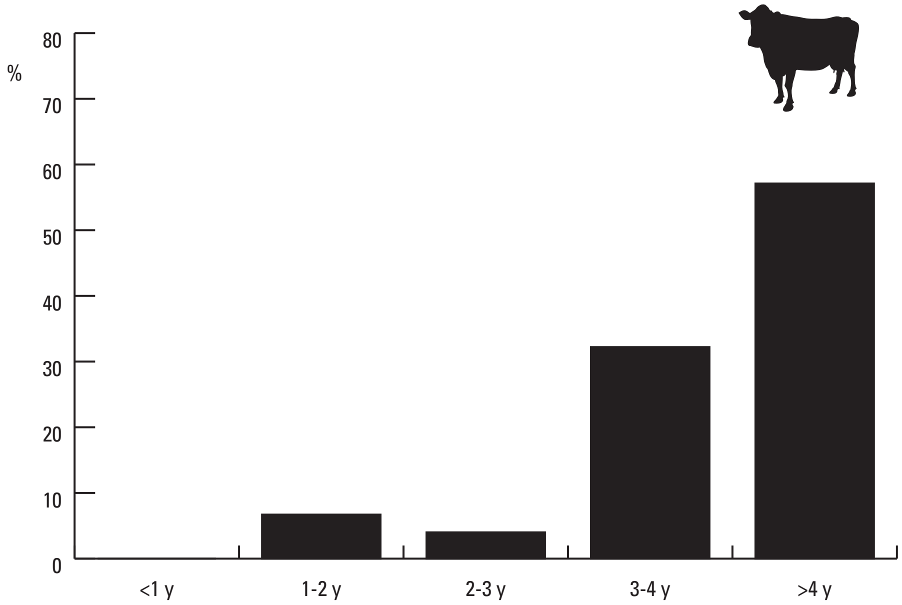

Fig. 6.19. Mortality profiles for cattle from Nijmegen 1bc, based on epiphyseal fusion (n=115).

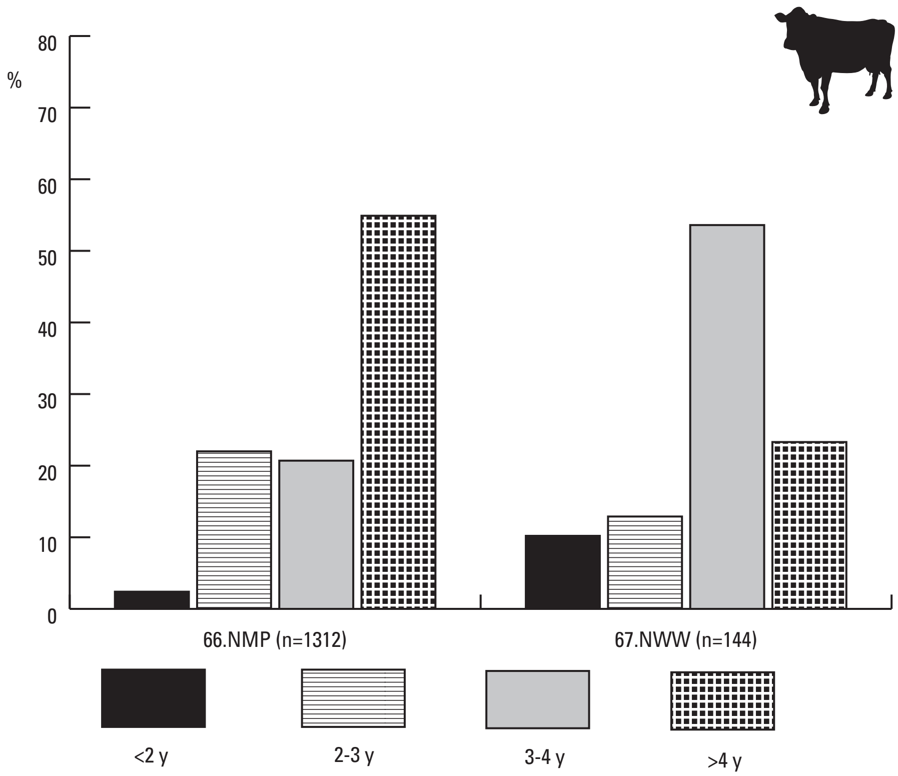

Fig. 6.20. Mortality profiles for cattle from Nijmegen-Maasplein and Nijmegen-Weurtseweg, based on epiphyseal fusion.

6.4.2.3 Cattle: epiphyseal fusion

For the Early Roman period, epiphyseal fusion data are available for Nijmegen 1bc. The proportion of unfused epiphyses is 13 %. It was possible to analyse fusion data in more detail. While adult cattle form the largest age class in Nijmegen 1bc, there is a substantial slaughter peak between three and four years

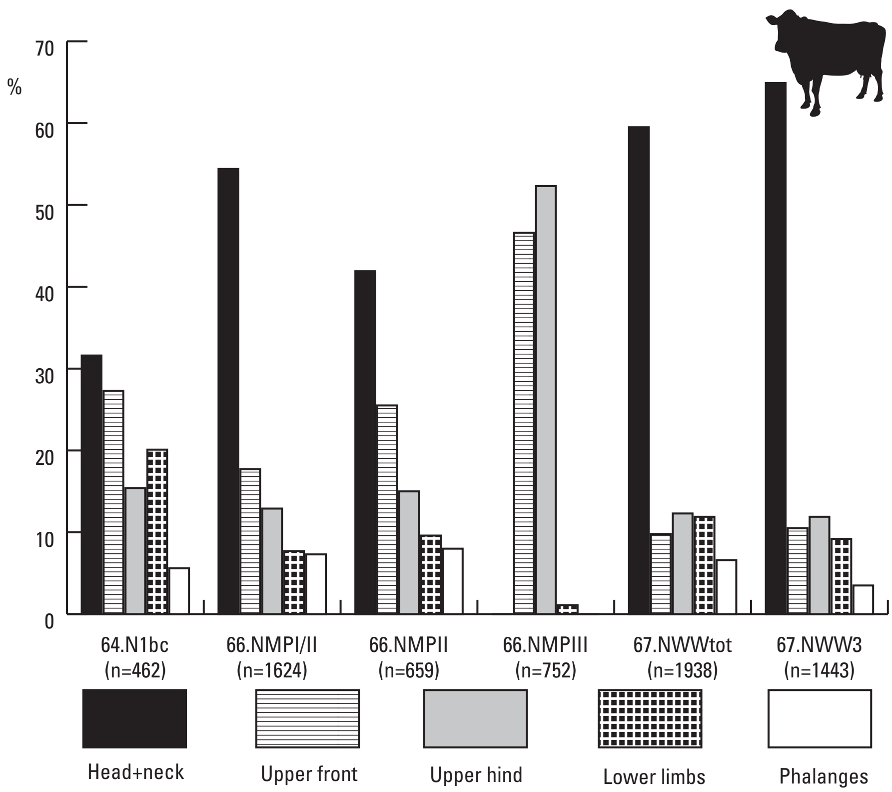

Fig. 6.21. Skeletal element distribution for cattle from urban assemblages (percentages out of the total number of fragments for the five categories).

(fig. 6.19). Very few cattle younger than three years were slaughtered. The two assemblages from urban Nijmegen have rather different proportions of unfused epiphyses: 11 % for Nijmegen-Maasplein and 26 % for Nijmegen-Weurtseweg. The more detailed analysis shows that Nijmegen-Maasplein consumed over 50 % cattle older than four years (fig. 6.20). For Nijmegen-Weurtseweg, the proportion of cattle older than four years is only 23 %. Nijmegen-Weurtseweg has a large slaughter peak of 54 % between three and four years. While Nijmegen-Maasplein also shows a significant peak for this age class, it is much smaller with 21 %. Both assemblages also show slaughter between two and three years. There is practically no slaughter of cattle younger than two years.

6.4.2.4 Other species

There are no urban sites that have yielded more than the minimum number of scored epiphyses for sheep or horse. The proportion of unfused epiphyses for pig in Nijmegen 1bc is 67 %.

6.4.3 Skeletal element distribution

6.4.3.1 Representation of cattle body parts

Of the urban assemblages, Nijmegen 1bc shows the most equal representation of the different body parts (fig. 6.21). The body part representation for Nijmegen-Weurtseweg was calculated for all phases, but is dominated by the 3rd-century butchery waste. Body parts for the two cattle butchery sites show an interesting difference: the assemblage from Nijmegen-Maasplein is composed almost exclusively of upper limb bones, while at Nijmegen-Weurtseweg fragments from the head and neck dominate. This pattern is even stronger when the 3rd-century material is regarded separately. In fact, Nijmegen-

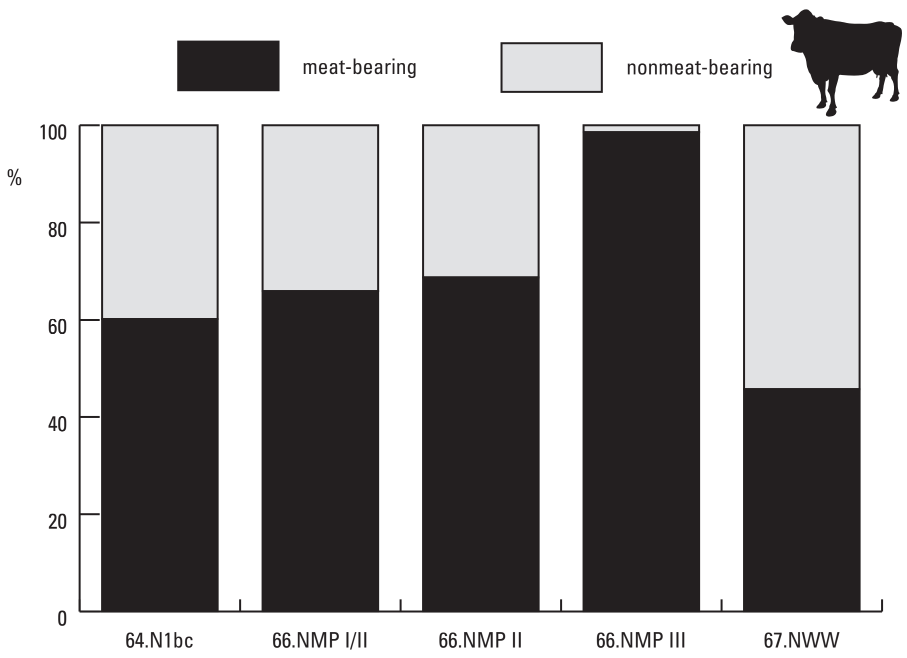

Fig. 6.22. Ratio of meat-bearing to nonmeat-bearing limb bones for cattle from urban/military assemblages (minimum number of fragments is 100).

Weurtseweg 3 seems similar to Nijmegen-Maasplein I/II, although the head+neck category is represented even better. What is clear is that the two butchery sites reflect different activities or stages in the processing of cattle.

6.4.3.2 Meat-bearing versus nonmeat-bearing limb bones

Figure 6.22 shows the proportions of meat-bearing and nonmeat-bearing bones for cattle. The proportion of meat-bearing bones is lowest in Nijmegen-Weurtseweg, while it is similar for the assemblages Nijmegen 1bc, Nijmegen-Maasplein I/II and Nijmegen-Maasplein II. The assemblage from Nijmegen-Maasplein III consists almost exclusively of meat-bearing limb bones, which fits with the interpretation of this assemblage as representing refuse from large-scale butchery. Proportions of meat-bearing limb bones for sheep in the two earlier assemblages from Nijmegen-Maasplein are 73 and 70 %. Although the sample size for pig was too low for all urban sites, the assemblage from Nijmegen 1bc comes close to the minimum number; the proportion of meat-bearing bones is 87 % (fig. 6.6).

6.4.4 BUTCHERY

Unfortunately, no information on butchery was available for the urban assemblages.

6.4.5 BIOMETRICAL ANALYSIS

6.4.5.1 Withers height

The number of withers heights from urban sites is small for all three species. Cattle, sheep and horse all show an increase in height from the Early to the Middle Roman period (table 6.7), but these results cannot be considered reliable.

	mean (cm)	n	range (cm)
cattle			
Early Roman[628]	117	3	114 – 119
Middle Roman[629]	124	6	111 – 135
sheep			
Early Roman[630]	59	4	56 – 62
Middle Roman[631]	63	3	60 – 68
horse			
Early Roman[632]	137	4	130 – 148
Middle Roman[633]	141	2	140 – 142

Table 6.7. Reconstructed withers height for cattle, sheep and horses from urban sites.

6.4.5.2 Log size index for cattle

Log size ratios for Early and Middle Roman Nijmegen can be compared, but only for width measurements, since the sample sizes for length measurements are very small and depth measurements are only available for Early Roman Nijmegen. Width measurements show a statistically significant increase between the Early and Middle Roman period (fig. E6.18; table E6.14).

6.4.6 ARCHAEOBOTANY

No archaeobotanical information was available for urban sites.

6.5 TEMPLES

Five assemblages from four different temples could be included in this study. Three of the temples have assemblages from an Early Roman or Late Iron Age phase preceding the construction of the Gallo-Roman temple and from the period in which the temple was used. Two assemblages are from the same temple site, but from different excavations: Elst-Grote Kerk and Elst-St. Maartenstraat. An assemblage from the Fortuna Temple in Nijmegen is included in this analysis, but is very different from the others, consisting almost completely of burned bird bones.

6.5.1 SPECIES PROPORTIONS

6.5.1.1 Species proportions for the four main domesticates per period

For Elst-Grote Kerk, Elst-St. Maartenstraat and Empel-De Werf, assemblages are available that predate the building of the first stone temples. The two assemblages from Elst are dominated by cattle (fig. 6.23; table E6.15). Cattle are also the main species at Empel, but with a much smaller propor-

628 All from Nijmegen 1bc. Data from Nijmegen-Oppidum Batavorum have not been included because no primary data were available. The mean for 42 withers heights, including the three withers heights from Nijmegen 1bc, is 117 cm. Robeerst 2005a, 84.

629 All from Nijmegen-Maasplein.

630 All from Nijmegen 1bc.

631 All from Nijmegen-Weurtseweg.

632 All from Nijmegen 1bc. Robeerst reaches a mean of 131.9 cm (range 124.6 - 136.8) for seven withers heights from Nijmegen-Oppidum Batavorum and Nijmegen 1bc, but does not include Lauwerier's largest measurement. Robeerst 2005a, 86.

633 Both from Nijmegen-Weurtseweg.

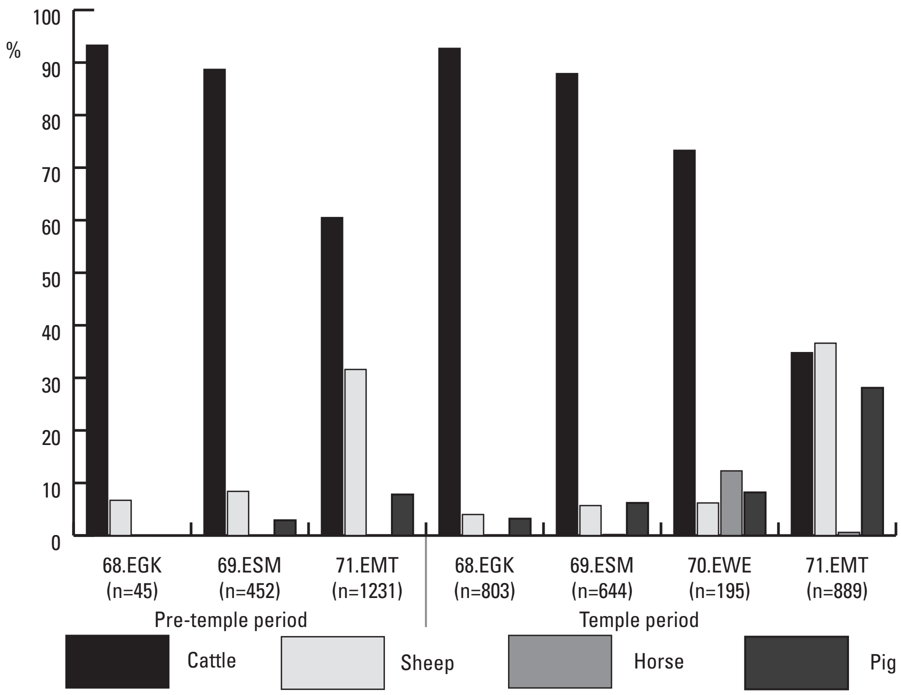

Fig. 6.23. Proportions for the four main domesticates for temple assemblages, based on the number of fragments, per assemblage.

tion. Sheep is the second species here with 32 %. Pig has a higher proportion in comparison to the other sites. The temple period starts around A.D. 50 in Elst-Grote Kerk/St. Maartenstraat, A.D. 10 in Elst-Westeraam, and A.D. 150 in Empel-De Werf.[634] Not surprisingly, the two assemblages from Elst-Grote Kerk and Elst-St. Maartenstraat are very similar. They are dominated by cattle, with low proportions of sheep and pig, and practically no horse at all (fig. 6.23; table E6.16). Species proportions are very similar to those of the previous period. The assemblage from Elst-Westeraam has a slightly lower proportion of cattle. Horse is represented by 12 % at this site, and sheep and pig have slightly higher proportions than in the assemblages from the other temple in Elst. The assemblage from the temple in Empel is completely different from those in Elst. Sheep is the main species here, with 37 %, followed by cattle with 35 % and pig with 28 %. It is unlikely that the difference in date has caused this, since sheep decline in number at most rural sites during the 2nd century A.D. The assemblage from the Fortuna temple in Nijmegen dates to the 2nd century A.D. The animal bones come from sieved samples from three pits located close to the temple. 98 % of the 693 fragments are from chicken (table E6.17). At least 16 birds are represented. The only other bird species present is quail. A few remains of cattle and sheep or goat were found, as well as some fish bones from herring, smelt and freshwater fish. With the exception of the fish bones, all bones were burned. A large number of fragments from mice, voles and shrews was interpreted as intrusive.[635]

[634] The temple in Empel was constructed in the Flavian period, but the animal bones date to the period A.D. 150-235.

[635] Zeiler 1997, 107. While dormice were a Roman delicacy, smaller rodents were probably not consumed. Varro: *De re rustica* III, 2, 12, 15; Apicius: *De re coquinaria* VIII, 9; Petronius: *Satyricon* XXXI, 10; Carpaneto/Cristaldi 1995; Groot 2013b; Kolling 1986; O'Connor 1986.

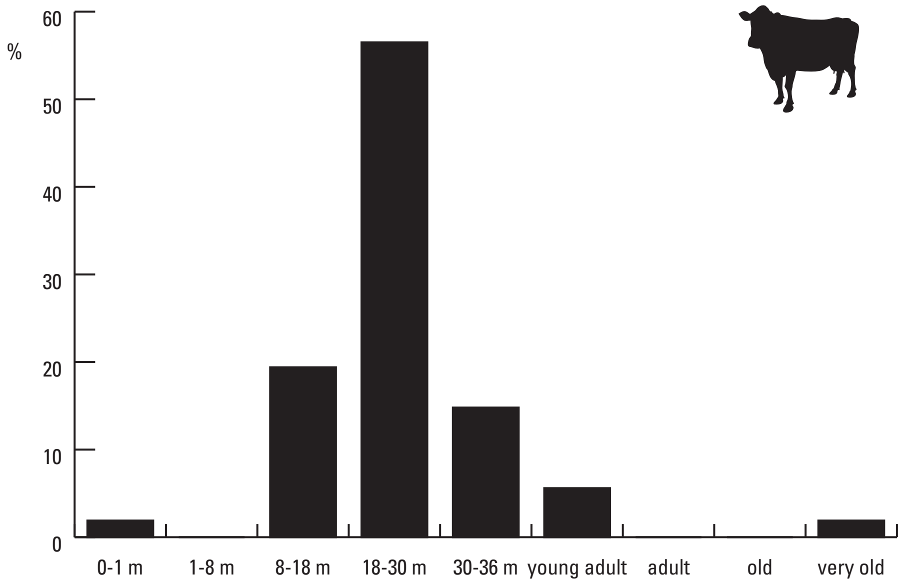

Fig. 6.24. Mortality profile for cattle for Elst-St. Maartenstraat, based on mandibular tooth eruption and wear (percentages out of the total number of aged mandibles, n=54).

6.5.1.2 Wild mammals

The only fragment of wild mammal from a temple site is a bone from a hare found in Empel-De Werf.

6.5.1.3 Chicken and seashells

Chicken is absent in the pre-temple periods and in Elst-Westeraam. In the temple periods of Elst-Grote Kerk, Elst-St. Maartenstraat and Empel-De Werf, the percentage of chicken is 0.1 to 0.5 % (table E6.5). This is in stark contrast to the percentage of chicken bones in the Fortuna temple, which is 99 %. Seashells were not found in any of the temples.

6.5.1.4 Wild birds and fish

In four of the five assemblages from temples, wild birds were present (table E6.7). Only 23 fragments were recorded (17 fragments of one individual were counted as one), but eight species are represented. Apart from ducks and geese (teal and diving duck *Aythya* sp.), these are cormorant (*Phalacrocorax carbo*), eagle owl (*Bubo bubo*), carrion crow, jackdaw (*Corvus monedula*) and common quail (*Coturnix coturnix*). Fish are only found in the assemblage from the Fortuna temple (table E6.8). The three fragments are from herring (*Clupea harengus*), smelt (*Osmerus eperlanus*) and a cyprinid.

6.5.2 EXPLOITATION OF LIVESTOCK

6.5.2.1 Sex determinations

In Empel-De Werf, 13 male and ten female sheep or goat were present. For pigs, seven boars and three sows were recorded.

6.5.2.2 Cattle: mandibular tooth eruption and wear

The temple assemblage from Elst-St. Maartenstraat has a very clear slaughter peak for the category 18-30 months, with some animals in the two categories to either side, and very few animals of other ages (fig. 6.24). The mandibular data from the temple period in Elst-Grote Kerk are not comparable with the system used here, but the conclusion was that 66 % of cattle were killed between 15 and 28 months. No primary data were available for Empel-De Werf and Elst-Westeraam. The publication on Empel-De Werf mentions that most mandibles are from cattle aged 15-28 months old. Cattle younger than 15 months were not found. At Elst-Westeraam, cattle were mainly slaughtered between 17 and 30 months. Robeerst sees slight peaks around the 24th and 30th month, and relates this to feasts in spring and autumn.[636] Since the number of mandibles is low, this seems to be stretching the data a bit far. In conclusion, all four assemblages show a strong slaughter peak between 15 and 30 months.

6.5.2.3 Cattle: epiphyseal fusion

Epiphyseal fusion data were not available for Elst-Westeraam. At Elst-Grote Kerk, 14 out of 15 epiphyses from the pre-temple period were unfused, indicating slaughter of young cattle. For the temple period, 90 % were killed in the second year of life. Lauwerier combined mandibular data with epiphyseal fusion data and concluded that most cattle would have been slaughtered during the second half of the second year of life, and some in the first half of the third year.[637] Data from Elst-St. Maartenstraat show that in the pre-temple period, nearly all cattle were killed before they were three years old. Slaughter in the first year could not be calculated due to the small number of epiphyses for this age category. In the temple period, the majority of cattle was killed before reaching the age of two years, with another 20 % killed in their third year. Very few cattle older than three years were killed here. Again, slaughter in the first year could not be calculated. The overall percentage of unfused epiphyses is 89.5 % for the pre-temple period and 80 % for the temple period. For the temple in Empel, no primary data were available. Around 80 % of cattle were killed between 15 and 30 months.[638] No animals younger than 15 months were present.

6.5.2.4 Sheep/goat

For Empel-De Werf, primary data were not available. The publication states that c. 90 % of the sheep were killed as adults, based on epiphyseal fusion.[639] For Elst-St Maartenstraat, ten sheep mandibles could be aged, most of which date to the pre-temple period. Seven of the mandibles are from sheep killed between one and four years old; one is between two and six years old, one between six and ten years, and one is older than three years.

6.5.2.5 Pig

Half of all the pigs at Empel-De Werf were killed in their second year, and the other half in their first or third year.[640] Two pig mandibles from Elst-St. Maartenstraat are from pigs aged 7 to 14 months.

6.5.2.6 Chicken

The chicken fragments found near the Fortuna temple are all from adult birds, with an overrepresentation of males (eight males, one female).

[636] Robeerst 2005b, 97-98.

[637] Lauwerier 1988, 116-117.

[638] Seijnen 1994, 165-166. Data for the pre-temple and temple period are discussed together.

[639] Seijnen 1994, 167. Data for the pre-temple and temple period are discussed together.

[640] Seijnen 1994, 167. Data for the pre-temple and temple period are discussed together.

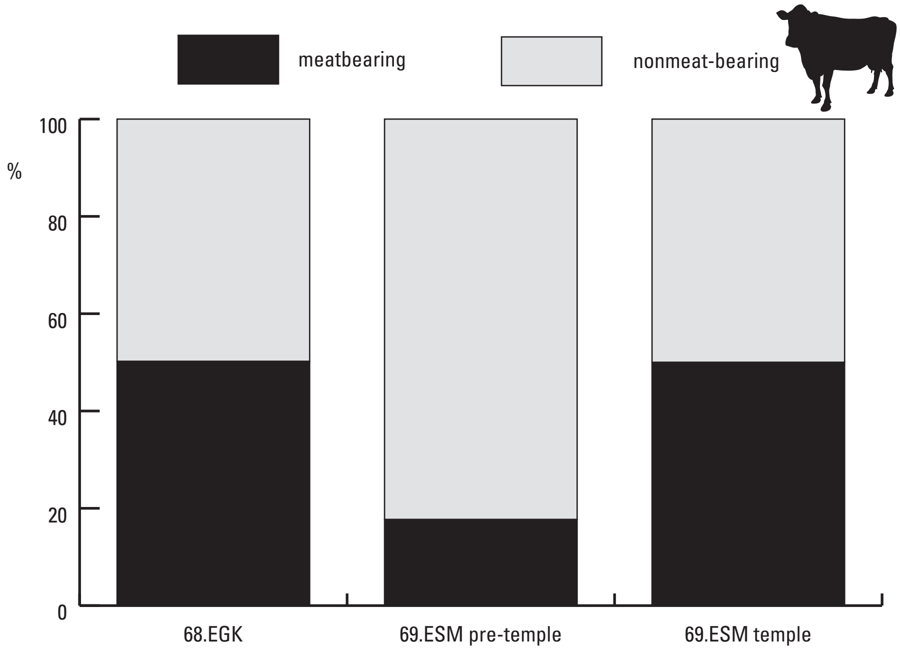

Fig. 6.25. Ratio of meat-bearing to nonmeat-bearing limb bones for cattle from temple assemblages (minimum number of fragments is 100).

6.5.3 Skeletal element distribution

6.5.3.1 Representation of body parts

The proportions for cattle upper limbs are on the low side, especially for Elst-Grote Kerk and Elst-St. Maartenstraat pre-temple phase (fig. E6.19). Lower limbs are well-represented. This suggests that cattle were butchered on the site, and that meat-rich parts may have been taken away from the temples, as Lauwerier suggested for sheep and pig.[641] At Empel-De Werf, more than half of all pig bones dating to the temple period are from the hind limbs, and fragments from the hind limbs are five times more common than fragments from the front limbs. Seijnen concluded that pigs were slaughtered outside the sanctuary, while the other animals arrived alive.[642] Although the number of fragments for pig is low, an overrepresentation of the upper hind leg is visible in the temple period in Elst-St. Maartenstraat. This suggests that these parts were brought to the temple. Since elements from all body parts are present, some pigs were probably slaughtered at the site.

6.5.3.2 Meat-bearing versus nonmeat-bearing limb bones

The proportions of meat-bearing and nonmeat-bearing cattle limb bones are exactly equal in the assemblages Elst-Grote Kerk and Elst-St. Maartenstraat (temple period), while there are only 21.5 % meat-bearing limb bones in the pre-temple assemblage from Elst-St. Maartenstraat (fig. 6.25). For sheep and pig, the assemblages were too small to calculate the ratio of meat-bearing to nonmeat-bearing bones.

641 Lauwerier 1988, 120.

642 Seijnen 1994, 165.

6.5.4 Butchery

The percentage of butchery marks on cattle bones in Empel-De Werf is 1.6 % (fig. 6.10). The ratio of chop to cut marks could not be calculated. For horse, either the number of fragments is too low or there was no information on butchery.

6.5.5 Biometrical analysis

6.5.5.1 Withers height

The number of withers heights from temples is very small; on their own, these data do not provide any information on changes over time (table 6.8).

	mean (cm)	n	range (cm)
cattle Early Roman[643]	114	2	113 – 114
cattle Middle Roman[644]	109	3	102 – 114
sheep (Middle Roman)[645]	59	2	55 – 63
horse[646]	134	1	-

Table 6.8. Reconstructed withers height for cattle, sheep and horses from temple sites.

6.5.5.2 Log size index for cattle

The number of measurements from temples is too small to allow any kind of analysis. Data from temple sites will be included in an overall comparison of consumption sites over time in paragraph 6.6.4.2.

6.5.6 Archaeobotany

Most of the cultivated plants found in Elst-Westeraam are cereals: emmer, barley, cultivated oat and one grain of spelt or bread wheat. Burned food remains were from bread and porridge. The only other food plant present was cherry. The archaeobotanical information for Empel-De Werf gives limited insight into the use of plants in the temple: it consists of one seed of a fig, elderberry seeds and pollen from different types of cereal. The cereal pollen is not interpreted as evidence for threshing, but rather as evidence for the presence of cereal sheafs or cereal products such as bread.[647] The assemblage from the Fortuna temple is remarkable: apart from some cereal grains, which may represent general settlement refuse, the assemblage consists of remains of fig, date and pine nut. Fig occurs in other sites, but date and pine nut seem to be related to funerary or other rituals.[648]

643 Elst-St. Maartenstraat.

644 Elst-Grote Kerk: 2 withers heights; Elst-St. Maartenstraat: 1 withers height.

645 Elst-Grote Kerk.

646 Elst-Westeraam.

647 Groenman-van Waateringe/Pals 1994, 78.

648 Hänninen/Vermeeren 1997. See also Bakels/Jacomet 2003, 553. Pine nuts are also found in secular contexts, for instance in *Vindonissa* and a Swiss *villa*.

6.6 DISCUSSION

6.6.1 THE CONSUMER DIET

6.6.1.1 Pig in military sites

It is clear that cattle were the main meat provider in the Roman period. However, in some sites other species have higher proportions than expected. Pig is the most common species in the Augustan camp in Nijmegen, which is the earliest of the military sites. Two other Early Roman sites with later dates show much lower proportions of pig: 21 % in Nijmegen-Trajanusplein and 10 % in Nijmegen-Kops Plateau. Cattle is the dominant species in these sites. Habitation at Nijmegen-Kops Plateau starts at the beginning of the Roman period, but this site has a much longer chronology, and if there was a high proportion of pig in the early part of the site's history, then this may have been hidden by the material from later years. The data from Nijmegen thus show an initial high proportion of pig, which rapidly decreases and is replaced by cattle. High proportions of pig – at least in comparison to rural sites in the region – are also found in Early Roman military sites elsewhere, such as Velsen 1 and 2, Valkenburg and Bodegraven in the western Netherlands (fig. 6.26), sites in Germany, such as Dangstetten (64 %),[649] Belgium, such as Tongeren-Kielenstraat (57 % in the earliest phase),[650] Switzerland, for instance Kaiseraugst (34 %),[651] and Britain, including Alchester (20 %).[652] The explanation that has been suggested and is commonly accepted is that early military establishments relied on their own food supply, and that the protein component was best reached by bringing and breeding their own pigs and chickens.[653] After all, pigs are prolific breeders, can be raised on a variety of foods, and quickly reach a good slaughter weight. Cavallo *et al.* observed high proportions of pigs in Early Roman military sites in their survey of the western part of the Dutch *limes*. Later in the 1st century A.D., when a local provisioning system was set up, the proportion of pig decreases.[654] Thomas does not exclude a local origin of the pigs in Alchester: "The fecundity of pigs, and the fact that they were only kept for their meat, may have meant that they were specifically targeted to provide a short-term maximisation of local resources for the army while local supply chains were being developed, or that they were specifically produced by rural communities for this purpose."[655] However, the date cannot be the only explanation, as the proportion of pig is higher in Velsen 2 than in Velsen 1. Zeiler suggests that this is related to turmoil at the time, due to attacks by Chaucian pirates and the invasion of Britain.[656] An alternative explanation is offered by King and Deschler-Erb, who explain the high proportion of pig in early military sites by the origin of the soldiers from regions where this species is preferred.[657]

The rapidly decreasing proportion of pig in the successive Early Roman sites in Nijmegen, in combination with the theory on the relation between an offensive army and a high proportion of pig, suggests that the offensive phase in the research area did not last long. The local supply of cattle was organised within the first decades, replacing the pigs that were bred and raised by the army itself. While the high proportion of pigs in the Early Roman sites can thus be explained by the lack of an established local supply system and the nature of the occupation, this does not explain the relatively high proportions of pig in the Middle Roman *castra* (23 and 29 %). In this case, an explanation should be sought in the food preferences and higher status of the legionaries stationed here. King noted a difference between legionary and non-legionary camps, with higher proportions of pig in the legion-

[649] Uerpmann 1977, 262.

[650] Ervynck/Vanderhoeven 1997. The earliest phase of this site probably represents military rather than civilian occupation.

[651] Deschler-Erb 1991, 122.

[652] Thomas 2008, 36.

[653] Cavallo *et al.* 2008, 74, 76, 78; Thijssen 1988, 64.

[654] Cavallo *et al.* 2008, 76.

[655] Thomas 2008, 36-37.

[656] Zeiler *et al.* 2010, 18.

[657] King 1984, 201; 1999, 183; Deschler-Erb 1991, 129.

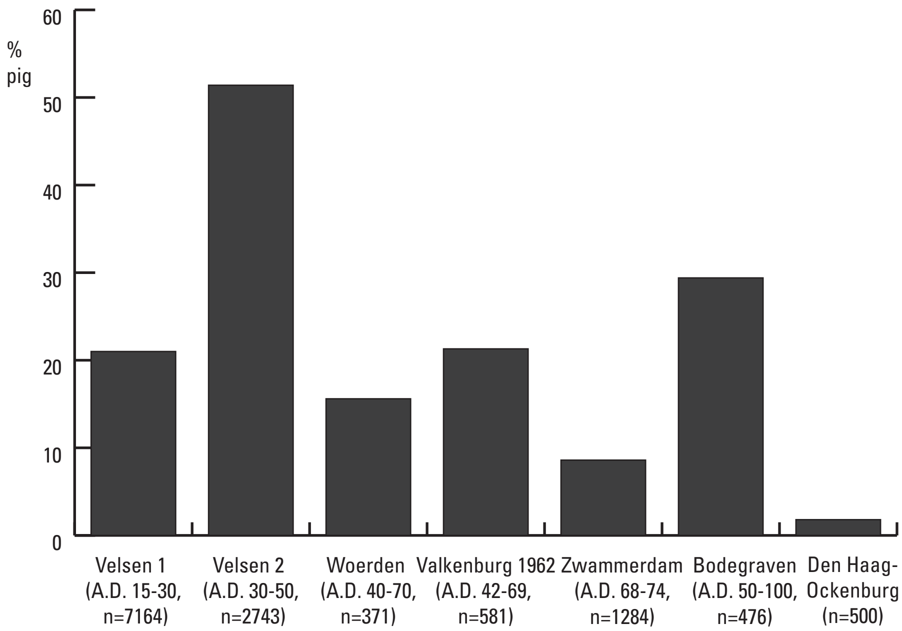

Fig. 6.26. Proportion of pig in military sites to the west of the research area (out of the total number of fragments for the four main domesticates). Data from Cavallo *et al.* 2008, Zeiler *et al.* 2010, Van Dijk 2008b, Prummel 1974, Van Mensch 1974, Lauwerier *et al.* 2005, Zeiler 2006.

ary camps.[658] It is also possible that the officers consumed more pork, or that meat from pigs was not supplied by the army but bought individually.

Proportions of pig are lower but still relatively high in Wijk bij Duurstede-De Geer 1 (17 %) and Meinerswijk (18.5 %). A preference for pork, or the keeping of some pigs in the military sites, could explain these higher proportions.

6.6.1.2 Sheep/goat

The two watchtowers in Utrecht-Leidsche Rijn both have a relatively high proportion of sheep or goat (32 and 24 %). One of the assemblages from the *castra* in Nijmegen also has a high proportion of sheep/goat (26 %), but since this was not found in the larger assemblage Nijmegen-Castra, this has probably more to do with variation within the site. Three of the urban assemblages (Nijmegen-Maasplein I/II, Nijmegen-Maasplein II and Nijmegen-Weurtseweg 1) and one urban/military assemblage (Kesteren-Vicus) also show relatively high proportions of sheep or goat, although not as high as the three military sites. It seems as if there was a difference in supply between the two watchtowers and the other military sites. Smaller livestock may have been more suitable for feeding a small group of soldiers than cattle, although cattle is still the main species in the watchtowers. Alternatively, the soldiers stationed in the watchtowers may have had a preference for mutton that was not shared by their colleagues in other military sites.[659] The high proportion of sheep in the assemblage from the *castra* may reflect a preference for mutton by the soldiers in that part of the camp. For urban Nijmegen, there seems to have been a difference in supply between the Early and Middle Roman periods. In chapter 7, the relation between these sites and the surrounding countryside will be discussed, to see whether the higher proportions are related to availability of sheep/goat.[660]

658 King 1984, 189; 1999, 183.

659 Deschler-Erb (1991, 129) explains the high proportion of sheep/goat in a *castellum* in Kaiseraugst by the Spanish origin of the soldiers stationed here.

660 King (1984, 193) explains the high proportion of sheep/goat in some early military sites in Britain by the restraints of local supplies rather than dietary preferences of the soldiers.

6.6.1.3 Horse

Five consumer sites show relatively high proportions of horse. This is especially striking considering the normally low proportions of horse in consumer sites (below 10 %). In the case of Nijmegen-Kops Plateau (13 %), a high number of horse bones was recovered outside the fort, even when two horse burials are disregarded. Considering these burials, it seems likely that the horse bones derive from other horses buried outside the fort. It is possible that horse meat was consumed in Utrecht-LR46V, and that this explains the proportion of horse of 21.5 %.[661] The assemblage Nijmegen-Weurtseweg 2 has a much higher proportion of horse than the earlier assemblage from this site (15 %). The assemblage was interpreted as butchery refuse because of the overrepresentation of phalanges and metapodials among the cattle bones.[662] That would suggest that horses were also butchered here. Elst-Westeraam is the only temple with a rather high proportion of horse (12 %). The highest proportion of horse in all consumer sites was found in Nijmegen IV: 24 %.

6.6.1.4 Chicken and seashells

Chicken is present in over half of the military sites, five of the seven assemblages from urban/military sites, all urban sites and four of the five temples. The assemblages where chicken is absent are all small, so it is suspected that the absence is by chance. Although chicken seems to be common, it is mostly represented by small numbers of fragments. Exceptions are the assemblage from the *castra* analysed by Thijssen and the Fortuna temple. Seashells are found less commonly than chicken, and are present in five of the military sites, three urban/military assemblages and two urban assemblages. Five species are recorded: oyster, mussel, periwinkle, whelk and cut trough shell.

6.6.1.5 Animals in temples

The difference in species between the Fortuna temple and the others is obvious. To some extent, the composition of animal bone assemblages from temples can be explained by the nature of the divinity that was worshipped.[663] Lentacker *et al.* convincingly argue for a symbolic relationship between the chicken, especially the cock, and the Mithras cult. If the dominance was due to gastronomic choice, females would be expected to be as common as males. Other animals for which a symbolic meaning within the Mithras cult is suggested are the jackdaw (replacing the raven) and the eel (representing the water snake).[664] The cock and male goat are known as companions of Mercury, which is reflected in the frequent occurrence of both species in the temple of Uley (UK).[665] While the chicken may also have had an association with Fortuna, it is perhaps not a coincidence that the Fortuna temple is situated right next to a second temple, devoted to Mercury. The animal bones were collected from pits outside the Fortuna temple and may represent refuse from the temple of Mercury as well as the Fortuna temple.

There are also differences in species proportions between the other temples, which are not so easy to explain. The animal bones from Elst-Grote Kerk/St. Maartenstraat are dominated by cattle. However, in the temple phase at Empel, sheep/goat and pig are of similar importance as cattle. The assemblages from Empel also show a development over time, with cattle declining and pig reaching a high proportion in the temple phase. Both the temples in Elst-Grote Kerk/St. Maartenstraat and Empel were devoted to Hercules Magusanus, so the difference in species proportions cannot be explained by the nature of the god. Perhaps the difference was not only caused by the character of the god that was worshipped, but also by the identity of the worshippers. However, there are no indications for differences in identity of the worshippers at Elst and Empel. The rural location of the temples suggests

[661] A single butchery mark was found indicative of consumption of horse meat. Groot 2010a, 267.

[662] Whittaker 2002, 201.

[663] King 2005, 357, 359.

[664] Lentacker *et al.* 2004, 72-74.

[665] King 2005, 333-334.

that they were used by indigenous people, in contrast to the urban temples. Initiation rites of young Batavian men seem to have been an important part of the cult, as well as the offering of military gear at the end of the period of military service.[666]

It is not known what god was worshipped at Elst-Westeraam, but it seems plausible that this would not be Hercules Magusanus, due to the proximity of the temple devoted to him in Elst-Grote Kerk/St. Maartenstraat.[667] The relatively high proportion of horse in Elst-Westeraam, which has already been mentioned above, is perhaps related to the divinity worshipped in Elst-Westeraam. Otherwise, species proportions are similar to those in the other temple in Elst, with cattle as the dominant species.

6.6.1.6 Wild mammals

Wild mammals are nearly absent in temples, and clearly played no role in the rituals carried out there or in ritual meals. Proportions of wild mammals are similar in urban/military and urban sites. In military sites, the proportion is highest, but even here it is so low that wild mammals are negligible when it comes to food supply. Perhaps the wild mammals found here represent animals hunted by officers or soldiers as a pastime. In military, urban/military and urban sites, red deer is the most common mammal and nearly all remains are from large game or hare. Only a few fragments from species usually hunted for fur were found, which suggests that game was primarily hunted for food.[668] Similar results are found in Britain and Northern France: game is also relatively rare there, and red deer and hare the most common species.[669]

6.6.1.7 Wild birds and fish

Remains of wild birds were found in 19 of the 24 consumer sites for which this could be established. The number of assemblages of each type is too small to say anything about presence or absence. Many of the bird remains are from ducks and geese, but a variety of other species is also present. A total of 31 species is represented. All the species could have been hunted in the area around Nijmegen. Birds were not only caught locally, but were also imported, as the pot with song thrush breasts found on the Kops Plateau proves.[670] Some of the remains from ducks and geese may have been from domestic birds. Domestic geese are known to have been kept north of the Alps.[671] Peters seems less convinced about domestic ducks, but Lepetz regards all duck and geese remains in his sites as domestic, with the caution that some may come from wild species.[672]

Fish remains are somewhat less common, and were found in half of the consumer sites. The presence or absence of fish remains is often related to whether samples were sieved or not. Some of the sites where sieving occurred, such as Nijmegen-Canisiuscollege and Utrecht-LR31, have yielded a large number of fish remains. In total, 24 different species were identified in consumer sites. While most of the fish species could have been caught locally, there are several saltwater species and one exotic species that were transported to Nijmegen. It is most likely that fish were transported preserved rather than fresh, and some evidence is found for this. Three chub mackerels were found in a pot on the Kops Plateau and had probably been salted, while a concentration of bones from the same species found in a latrine could represent fish sauce.[673] Chub mackerel is a fish of more southern waters, and has also been found in Roman Velsen and Tongeren.[674]

[666] Derks 2005, 24-25; Roymans 2004, 246-248.

[667] Derks 2005, 29. Derks also suggests a difference in the nature of the cult between the two temples in Elst, with a public cult in Elst-Grote Kerk/St. Maartenstraat and a private cult in Elst-Westeraam. This is based on the difference in size.

[668] Of course, hunting for fun is another explanation.

[669] Cool 2006, 112; Lepetz 1996, 102, 105.

[670] Lauwerier 1993.

[671] Peters 1998, 195, 233-234.

[672] Lepetz 1996, 126-131.

[673] Lauwerier 1993; 2009, 162.

[674] Brinkhuizen 1989; Vanderhoeven *et al.* 1994.

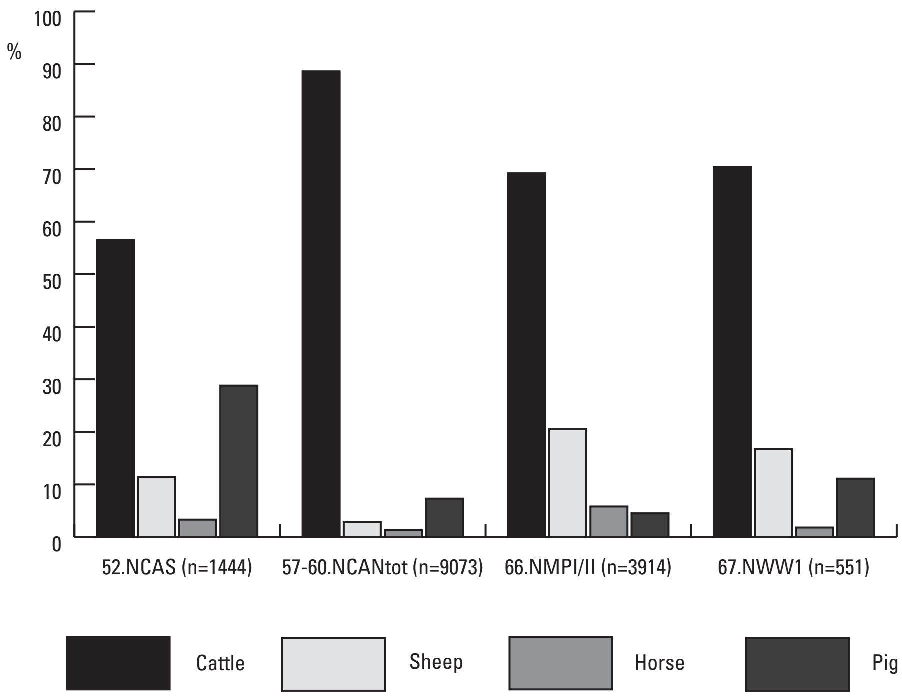

Fig. 6.27. Proportions for the four main domesticates for Middle Roman Nijmegen, based on the number of fragments, per assemblage.

6.6.1.8 Urban and military Nijmegen

To find out whether there was a difference between military and urban supply in Early Roman Nijmegen, the results from Nijmegen-Kops Plateau and Nijmegen 1bc/Nijmegen-Oppidum Batavorum can be compared. Cattle is the dominant species in all three assemblages, but has the highest percentage in Nijmegen-Kops Plateau (fig. E6.20). Sheep is slightly more common in the urban assemblages. In the two urban assemblages, horses make up 3 % of the total, while in Nijmegen-Kops Plateau this percentage is 13 %. Pigs are more common in the urban assemblages; this is especially noticeable in the Nijmegen-Oppidum Batavorum assemblage. It is not clear why there is such a difference in the proportion of pig between the two urban assemblages, but perhaps this is related to the extent of sieving.

For the Middle Roman period, the two urban assemblages are rather similar, although there are slightly more sheep and horses in Nijmegen-Maasplein I/II and slightly fewer pigs (fig. 6.27). The main species is cattle with 69-70 %. The *canabae* has a much higher proportion of cattle, leaving the other species with very small proportions. The *castra* has the lowest proportion of cattle of the three sites, and a high proportion of pig. The latter has already been discussed above and can be related to food preferences of legionaries and/or officers. Proportions of sheep are relatively high in the urban assemblages.

6.6.1.9 Nijmegen-Kops Plateau: differences between inside and outside the fort

Whittaker considered the differences in species proportions (with the lowest percentage of pig found inside the fort) between the different zones on the Kops Plateau surprising considering that the inside of the fort was occupied by the army elite (army officers and legionary soldiers), while auxiliary soldiers were stationed outside.[675] His expectation was that the elite would consume more pig. He explains the

[675] Whittaker 2002, 142.

higher proportion of pig outside the fort by a possible Mediterranean origin of the auxiliary soldiers, and a cultural preference for pork.[676] However, it is not clear of what origin the soldiers inside the fort were if not Mediterranean. The age of cattle consumed inside the fort is considerably higher than that of cattle consumed outside the fort. Again, this goes against Whittaker's expected consumption pattern for a Roman elite, which he believes should consist of younger animals.[677] The assemblage from outside the fort also contains a higher proportion of deer. Auxiliaries may have been likelier to hunt to supplement their diet. The high percentage of horse outside the fort is easier to explain. A large horse stable complex shows that horses were kept here, and two horse graves show that casualties were buried close by.[678] The horse remains probably derive from disturbed graves, or from horses that were skinned and then discarded.[679]

6.6.2 Exploitation of livestock

6.6.2.1 Exloitation of cattle

In most of the military sites, the majority of cattle was slaughtered at an adult age with a smaller amount of animals killed at a prime meat age. Exceptions are the Augustan camp in Nijmegen and Utrecht-LR31, where nearly half of all epiphyses were unfused and thus from nonadult cattle. This combination of exploitation for meat and keeping cattle for secondary purposes is also found in the urban/military and urban sites, but an exception is formed by the *vicus* in Utrecht-Leidsche Rijn, which shows a different pattern, with only 35 % of cattle composed of adult and older animals. The two assemblages from the *vicus* have different peaks, however: 18-30 months at Utrecht-LR58 and young adult at Utrecht-LR46V. The *canabae* in Nijmegen shows a mix of adults and prime meat cattle (18-30 months). Whittaker suggested that the cattle in the *canabae* were primarily raised for meat by rural providers, with a handful of older animals used for other purposes. He assumed that the optimum slaughter age for cattle was around 5 years. However, we have seen from the mortality profiles in the rural sites that cattle raised for meat are slaughtered much earlier, between 8 and 36 months.[680] If this was considered the best age to kill meat animals, there is no reason why cattle destined for the urban and military markets would be kept on for at least a further 2.5 years. A mix of younger and older cattle is found at Nijmegen-Maasplein, while older cattle dominate the assemblage from Nijmegen-Weurtseweg.

When Early Roman urban and military Nijmegen are compared, the proportion of unfused epiphyses for cattle is the same for both Nijmegen-Kops Plateau and Nijmegen 1bc: 13 %. However, a more detailed analysis shows that there is a difference in when cattle were slaughtered (fig. 6.28). While both sites show little slaughter in the first two years, there is slightly more slaughter in the third year in the military site. In the fourth year, there is a much larger difference, with only 7 % of cattle killed in this category at Nijmegen-Kops Plateau and 32 % in Nijmegen 1bc. As a result, survival beyond four years is much higher in Nijmegen-Kops Plateau.

For Middle Roman Nijmegen, slaughter of adult cattle is highest in the *castra*, but Nijmegen-Maasplein I/II is not far behind; in the *canabae*, more nonadult cattle were slaughtered (fig. 6.29).[681] In the *castra* and Nijmegen-Maasplein I/II, slaughter of nonadults is equal in the third and fourth years. In the *canabae*, nonadult cattle are also slaughtered in their fourth year, but even more in their third year.

676 Whittaker 2002, 145.

677 Whittaker 2002, 149.

678 Van Enckevort/Zee 1996.

679 The horse burial that Whittaker studied showed evidence for skinning but not consumption. Whittaker 2002, 143.

680 See paragraph 5.9.2.

681 Epiphyseal fusion data for Nijmegen-Weurtseweg were not available per phase, and have therefore not been included in the discussion here.

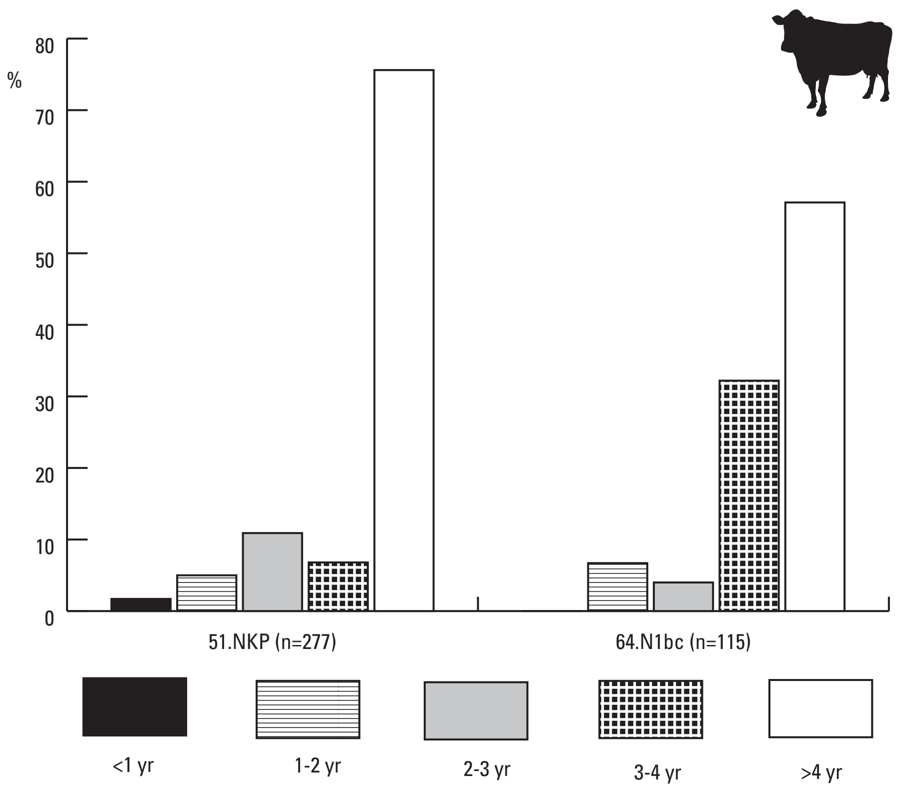

Fig. 6.28. Mortality profiles for cattle from military and urban Early Roman Nijmegen, based on epiphyseal fusion.

While some of the cattle supplied to consumer sites were certainly raised as meat animals, most were first used for secondary purposes. A similar situation is found in consumer sites outside the research area. In Belgium, mainly adult animals were found in Tienen-Grijpenveld (period A.D. 70-140), Tongeren-Veemarkt and Tongeren-Momberstraat, while both young and adult cattle are present in Tongeren-Kielenstraat.[682] The mixture of old cattle used primarily for traction and younger cattle raised primarily for meat is also noted by Pigière.[683] In Winchester, most cattle were older than four years, but few seem to have been very old.[684] Cattle in Lincoln were also mostly older than four years, and probably around eight years old at the time of slaughter.[685] Peters presents age data from several sites in *Germania Inferior*, *Germania Superior*, *Raetia* and *Noricum* which show a combination of animals raised for meat and older animals kept for traction. Generally, slaughter ages are higher than in the preceding period.[686] In Northern France, some towns have a majority of young cattle, while in others older animals dominate.[687]

It is not surprising that the temples show a very different pattern: here, there is a very strong emphasis on cattle between 18 and 30 months old, with very few animals of other ages. Clearly, only the best beef animals were selected for slaughter and consumption in temples.

Unfortunately, there is hardly any information on the sex of cattle in the research area. Therefore, we have to look at other regions. In the *castellum Asciburgium*, mainly cows were recorded.[688] In Magdalensberg and Xanten, cows were also more common than male cattle.[689] However, according

682 Martens 2012, 288; Pigière/Lepot 2013, 232; Vanderhoeven *et al.* 1993, 179-182.

683 Pigière 2014.

684 Matlby 2010, 143-146.

685 Dobney *et al.* 1996, 30.

686 Peters 1998, 67.

687 Lepetz 1996, 84.

688 Deschler-Erb 2007, 34. It is suggested that the cows were kept for milk by indigenous people.

689 Peters 1998, 64.

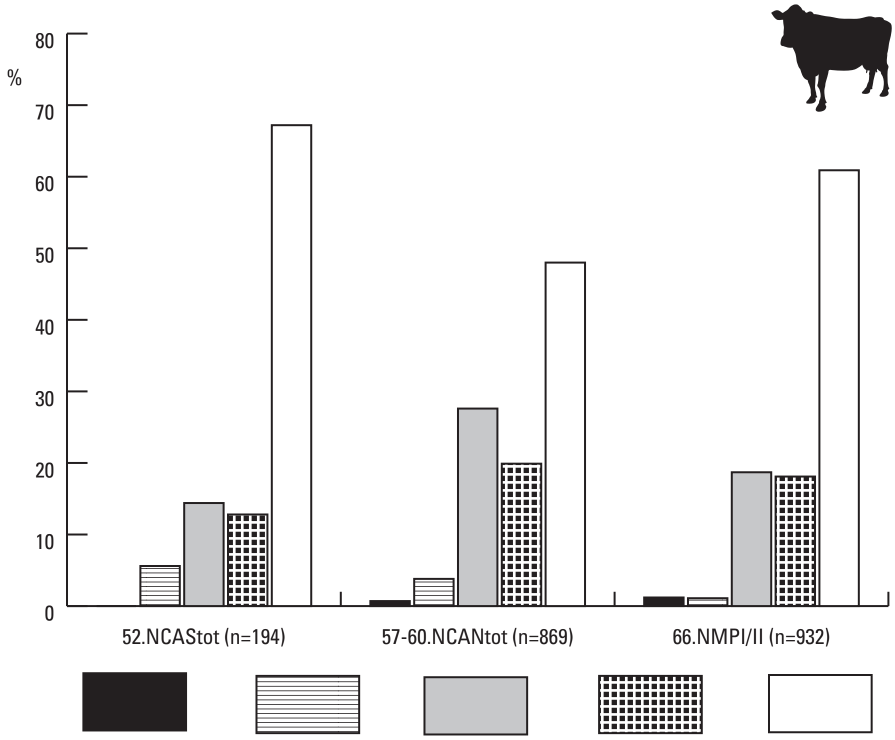

Fig. 6.29. Mortality profiles for cattle from Middle Roman Nijmegen, based on epiphyseal fusion.

to Peters, male cattle generally outnumber cows in most sites in *Germania Superior* and *Raetia*; specific examples are the *vici* Hüfingen and Bad Wimpfen.[690] Peters explains the higher number of males by the importance of oxen for ploughing and transport. In Winchester, cows outnumbered male cattle.[691]

6.6.2.2 Exploitation of sheep/goat

Sheep are much more common than goats in all types of consumer site. Unfortunately, age data for sheep are limited. Nijmegen-Castra has a higher proportion of unfused epiphyses (and thus nonadult sheep) than Nijmegen-Kops Plateau. This would suggest that in the Flavian period, more sheep were supplied to the army at a prime meat age than earlier. A similar proportion is found in the *canabae*; on the other hand, the mandibular data indicate mainly adult sheep. Male sheep outnumbered female sheep, but not to a great extent.

6.6.2.3 Exploitation of pig

It is no surprise that pigs are slaughtered at a young age, but a difference is visible between the Augustan camp and Nijmegen-Castra on the one hand (over 60 % unfused; the *canabae* and Nijmegen 1bc could also be added here), and Nijmegen-Kops Plateau and Nijmegen-Valkhof on the other hand (44 and 47.5 % unfused). It is not clear if this says anything about the origin of the pigs. Pigs younger than one year are absent at Nijmegen-Kops Plateau, which argues against the breeding and raising of pigs in the camp. Perhaps pigs were kept in the Augustan camp and the Flavian *castra*, where they were killed as soon as they reached a reasonable weight. Larger, older pigs were imported to Nijmegen-Kops Plateau, which explains both the presence of more adults and the absence of the youngest age category. With the limited amount of data available, however, this will remain speculation. Male and female pigs are equally represented in consumer sites.

[690] Peters 1998, 65-66.

[691] Maltby 2010, 147-150.

6.6.2.4 Exploitation of horse

Because horses are generally not well represented in consumer sites, age data are limited. However, the overall impression is that most horses lived to an adult age. The low proportion of young horses can also be explained by an absence of breeding in consumer sites, with horses mostly coming to these sites as adults.

6.6.2.5 Exploitation of livestock in temples

The question is to what extent the exploitation of animals in temples represented an economic loss. The main impact would have been on cattle, and only at Empel-De Werf on sheep and pigs. Since the meat from the animals killed in temples was consumed, the economic loss was limited. The temple sites show a clear selection of young cattle of 1.5-2.5 years old. This was believed to be a special selection for ritual consumption.[692] However, this is the exact age at which we see a slaughter peak in the rural settlements. The consumption of young cattle is clearly not specific to temples; only the degree differs. Even that is not surprising, since at temple sites we only find meat consumption, and do not have the background noise of production found in rural sites, consisting of breeding stock which was killed at much older ages. There is a difference between the temples and the urban and military consumption sites, which seem to consume older cattle. Only young cattle were suitable for sacrifice or consumption in the temples, while the town and army had to accept older animals as well.

6.6.3 BUTCHERY, PROCESSING OF MEAT AND SUPPLY WITH PRESERVED MEAT

6.6.3.1 Cattle and movement of cattle body parts

The proportion of head+neck fragments is very high in Nijmegen-Kops Plateau, while only few lower limbs and phalanges are present. The underrepresentation of the feet can be explained by slaughter in a different location and/or supply with meat (heads?) rather than live cattle. It is not clear how the dominance of fragments from the head and neck should be explained. Since the assemblage was collected from what seems to be a representative section of the site, this overrepresentation cannot easily be explained by selective dumping of refuse or processing of cattle in certain areas. Skeletal element analysis for the different zones of Nijmegen-Kops Plateau suggests that better cuts of meat were consumed inside the fort, which fits in with the hypothesis that the fort was occupied by the army elite.[693] There is a high proportion of meat-bearing limb bones in Nijmegen-Kops Plateau (75.5 % compared to 60 % in Nijmegen 1bc). This could mean that meat-bearing portions as well as cattle heads were brought to the military camp.

In Utrecht-LR31, there is a high proportion of upper limb bones, which suggests supply of joints of meat. This would be fitting for a watchtower with only a small group of soldiers present. The temple assemblages Elst-Grote Kerk and Elst-St. Maartenstraat show a high proportion of lower limb bones. Cattle seem to have been slaughtered here and some of the meat-rich parts taken away, probably back to the rural sites where they were consumed.

6.6.3.2 Large-scale processing of cattle carcasses in urban Nijmegen

Typical for Roman towns is the large-scale processing of cattle by professional butchers. Refuse from such activities consists of animal bone assemblages dominated by cattle bones (up to 99 %), which are

[692] Lauwerier 1988, 120-121. Lauwerier contrasts the age of cattle at Elst-Grote Kerk with that in the other sites in his study, where the average age of cattle is older: "the pattern of ages of cattle at the time of slaughter for the temple period deviates conspicuously from that of normal meat-providing animals". However, his data include urban and military sites, which do seem to consume older animals compared to rural sites.

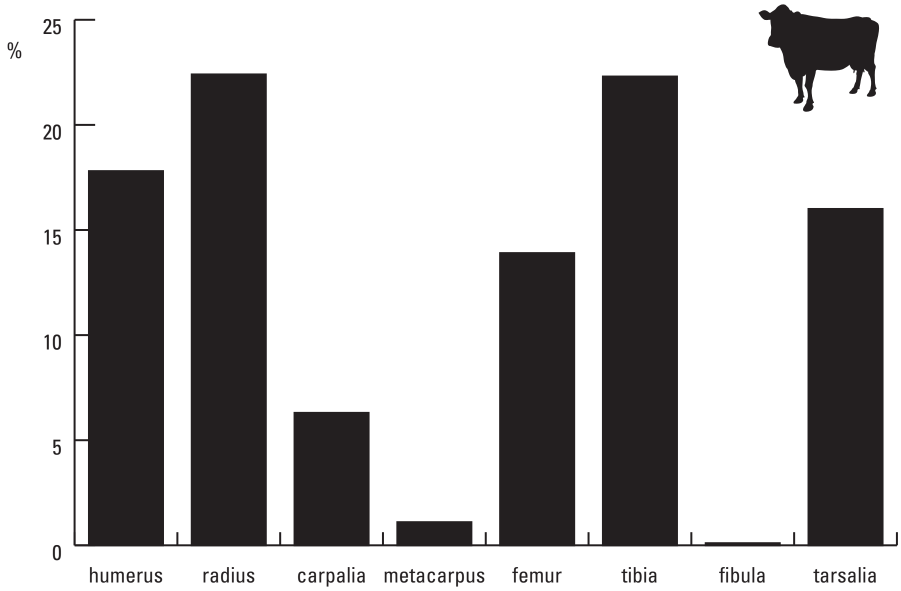

Fig. 6.30. Skeletal elements of cattle represented at Nijmegen-Maasplein III (percentages out of the total number of fragments, n=753).

heavily fragmented. Particular skeletal elements dominate. Products besides meat that were delivered by these butchers or passed on to other specialists are marrow, horns, skin and bone for boneworking.[694] Refuse from the various steps involved in the industrial processing of cattle carcasses have been found in Roman towns, such as concentrations of horncores related to hornworking and tanneries, boneworking waste and the production of marrow and glue.[695] A problem with the data from large consumer sites such as towns is that they are seldom representative for the entire site. This is especially problematic for *Ulpia Noviomagus*. It is to be expected that industrial activities such as tanning, hornworking and boneworking would have taken place here, but the only evidence for large-scale activities is related to the processing of meat and perhaps the extraction of grease. Unless a tannery or hornworking workshop or the location where refuse from these activities was dumped is excavated,[696] general skeletal element distribution for an urban site does not say anything about the presence of these activities.

Cattle carcasses are typically butchered heavily in towns, resulting in a high frequency of butchery marks and a high degree of fragmentation. This is due to the intensive exploitation in order to maximise the food supplied per animal, the different tools used by the butchers, and the different methods of disarticulation.[697] Two of the assemblages from *Ulpia Noviomagus* are cattle butchery sites: specialised places where cattle carcasses were processed. Not surprisingly, they are characterised by an overwhelming dominance of cattle fragments (more than 99 %). Both assemblages date to the 3rd century. Despite these similarities, the skeletal elements show striking differences. The assemblage from Nijmegen-Maasplein III shows a clear selection of upper limb bones (fig. 6.30). In Nijmegen-Weurtseweg 3, the head+neck is overrepresented; furthermore, the proportion of meat-bearing limb

693 Whittaker 2002, 144-145. Unfortunately, the animal bones have a broad date, so cannot be related to specific occupation phases of the fort.

694 Maltby 1989, 75; 2010, 287.

695 Ervynck 2011; Lepetz 1996, 145-146; Maltby 1989, 75; Stokes 2000; Vanderhoeven/Ervynck 2007, 164-166, 168-171.

696 Good examples are known for Augst. Deschler-Erb 2012a; 2012b; Schibler/Furger 1988; Schmid 1968; 1972.

697 Maltby 1989, 89, 91.

bones is much lower than in Nijmegen-Maasplein III. While the dominance of meat-bearing bones in Nijmegen-Maasplein III could indicate butchering for meat (removing meat from the elements richest in meat), a similar selection of elements is seen in waste from gluemaking in Augst and Arras.[698] A similar assemblage from York was interpreted as refuse from the extraction of fat or stock.[699] The assemblage from Nijmegen-Weurtseweg 3 seems to represent the initial butchering of cattle and processing of the head. What is clear is that the two urban assemblages represent different activities, but which are both related to the large-scale processing of cattle. A Late Roman assemblage from Lincoln indicates large-scale, systematic slaughter of cattle and production of marrowfat.[700] Cattle butchery sites are also found in Northern France.[701] Oueslati`s research on Roman butcheries in Gaul highlights the scale of the operations, with at least 2400 cattle represented in one site.[702] The variation in size and morphology of cattle in Paris suggests that they came from a large region.[703]

6.6.3.3 Specialised processing of meat in the canabae

There is evidence for several stages of butchery and meat processing in the *canabae*, from primary butchery to specialised production of smoked shoulders of beef and brawn. There are also indications for consumption, such as pits containing meat-bearing elements of cattle. I have suggested earlier that the shoulderblades are more likely to represent consumption waste, in this case from an inn or butcher's shop.[704] Some of the meat products from the *canabae* may have been destined for the *castra*, but the *castra* seems to have procured and butchered most of its own supply of beef.[705] If initial butchery of cattle to provide the *castra* with meat took place in the *canabae*, then lower limbs and phalanges would be underrepresented in the *castra* and overrepresented in the *canabae*. However, these elements are better represented in the *castra* than in the *canabae* (fig. E6.21).

6.6.3.4 Pig: whole pigs vs supply of preserved meat

The proportion of meat-bearing limb bones is much lower for the Augustan camp than for Nijmegen-Kops Plateau and Nijmegen-Castra. One explanation for this is that more pigs were slaughtered inside the Augustan camp – with all their remains ending up in the site – compared to the later sites, and that in the later sites preserved meat formed part of the supply of pork – with only the meat-rich parts being transported to the site. That would mean that the supply of preserved pork already developed during the 1st century. However, it would then be logical to assume that production of preserved pork took place in the urban and urban/military sites close to the military sites. This should result in higher proportions of nonmeat-bearing limb bones. This is not found in the data from Nijmegen 1bc (A.D. 25-70) or the Flavian *canabae*; proportions of meat-bearing elements are high in both sites. If preserved pork was supplied to Nijmegen-Kops Plateau and the *castra*, then it seems to have come from further away. The temples also provide indications for the movement of body parts of pig: upper hind limbs are overrepresented at Empel-De Werf and Elst-St. Maartenstraat. Some pigs were certainly slaughtered on-site, but additionally the meat-rich upper hind limb seems to have been brought here.

698 Deschler-Erb 2006a; Lepetz 1996, 145-146.

699 O'Connor 2000b, 54-55.

700 Dobney *et al.* 1996, 24-28.

701 Lepetz 1996, 144-146.

702 Oueslati 2005.

703 Diversity in cattle size was also found in Tongeren, although this could also be related to the long time period covering the measured bones. Pigière/Lepot 2013.

704 As has also been suggested by Dobney *et al.* 1996, 27.

705 Lauwerier 1988, 59-61; Whittaker 2002, 218-219.

6.6.3.5 Butchery marks on cattle and horse bones

The percentage of butchery marks on cattle bones in consumer sites is very variable and ranges from below 2 % (Utrecht-LR46V and Empel-De Werf) to 67 % for Nijmegen-Canisiuscollege. The ratio of chop to cut marks also varies a lot, from 1.33 for Wijk bij Duurstede-De Geer 1 to 33 for Nijmegen-Canisiuscollege. A comparison between superficial chop marks and chop marks cutting through the bone could only be made for Wijk bij Duurstede-De Geer, where the first type makes up 53 % of butchery marks.

There is little information on butchery of horses. Butchery marks were found on horse bones from Utrecht-LR31, Wijk bij Duurstede-De Geer, Nijmegen-Canisiuscollege, Utrecht-LR46V and Utrecht-LR58, but in all cases in very low numbers. As far as it was possible to tell, butchery marks indicate segmentation rather than consumption. The only unequivocal evidence for consumption of horse meat was found in refuse from the *vicus* or *castellum* at Kesteren (precise context unknown): a scapula with a hole in the blade that is associated with hanging for smoking.[706] It also shows the scraping marks usually interpreted as removing smoked meat (tougher to remove than unsmoked meat) from the bone.

6.6.4 Biometrical analysis

6.6.4.1 Withers height

Withers heights of cattle show an increase over time where this could be studied, i.e. in military sites, where the largest increase is found in the Late Roman period, and urban sites. The mean withers height for cattle in urban/military sites is similar to that for Middle Roman military sites. The mean withers height in urban sites is higher than that in military sites in both the Early and Middle Roman period; however, only a few withers heights were available for urban sites. For sheep, a small increase in withers height is noted in military sites in the Middle Roman period. A similar increase in withers height is noted in the urban assemblages, even though the data are very limited. Horses from urban/military sites have a higher mean withers height than those from Middle Roman military sites, but the number of withers heights is especially low for the latter category. Urban horses seem to show an increase in withers height in the Middle Roman period, but again, the numbers are very low.

6.6.4.2 Log size index for cattle: changes over time

The lack of a statistically significant increase in length and depth measurements from the Early to Middle Roman period in military sites can perhaps be explained by the dating of the measurements. Among the width measurements, Nijmegen-Castra and Wijk bij Duurstede-De Geer 1 are equally well represented, with the latter site dating after A.D. 150. However, measurements from the Flavian Nijmegen-Castra dominate the length and depth measurements. An increase in size may have been gradual and not become really noticeable until later in the Middle Roman period.

LSI data from all consumption sites have been pooled per period to trace any broader developments in size and shape of cattle. No significant changes occur in width and length measurements between the Early and Middle Roman periods, but the Late Roman period shows a statistically highly significant increase for all dimensions (figs. 6.31-33; table E6.18). In addition, depth measurements show a statistically significant increase in the Middle Roman period.

[706] Zeiler 2005. Since the small assemblage was only assessed, it is not included in this study.

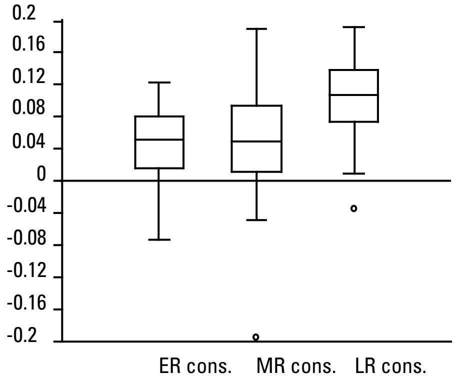

Fig. 6.31. LSI for width measurements for cattle from all consumer sites together, per period.

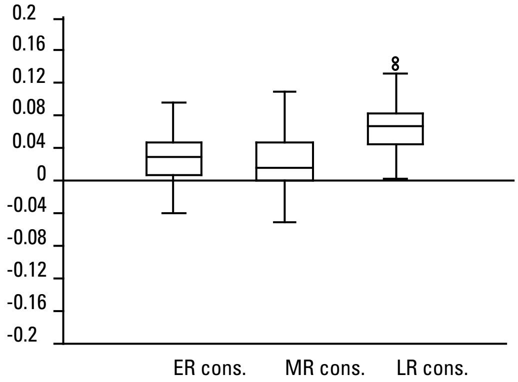

Fig. 6.32. LSI for length measurements for cattle from all consumer sites together, per period.

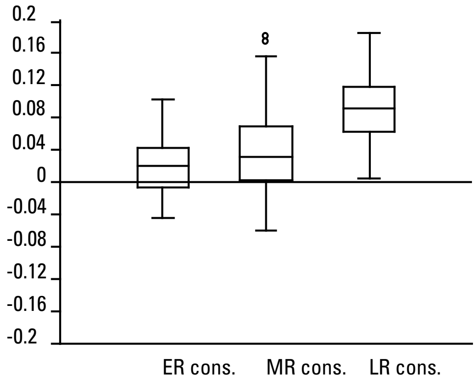

Fig. 6.33. LSI for depth measurements for cattle from all consumer sites together, per period.

6.6.4.3 Log size index for cattle: differences between contemporary sites

A comparison between contemporary sites of a different type could reveal different sources of cattle. In this study, it was possible to compare sites for Early and Middle Roman Nijmegen. For Early Roman Nijmegen, urban (Nijmegen 1bc) and military (Nijmegen-Kops Plateau) sites could be compared. A statistically significant difference is only found for width measurements, which are larger in Nijmegen-Kops Plateau (fig. 6.34; table E6.19). The means for the other measurements are also larger in Nijmegen-Kops Plateau, but the difference is not statistically significant (figs. E6.22-23).

For Middle Roman Nijmegen, data from the *castra*, *canabae* and urban Nijmegen-Maasplein I/II could be compared.[707] No statistical differences were found between the *castra* and *canabae*, or between the *canabae* and Nijmegen-Maasplein I/II (figs. 6.35, E6.24-25; table E6.20). However, there is a statistically highly significant difference between the length measurements from the *castra* and Nijmegen-Maasplein I/II, with measurements from the latter site being larger (fig. 6.35).

[707] For Nijmegen-Maasplein I/II, no depth measurements were available.

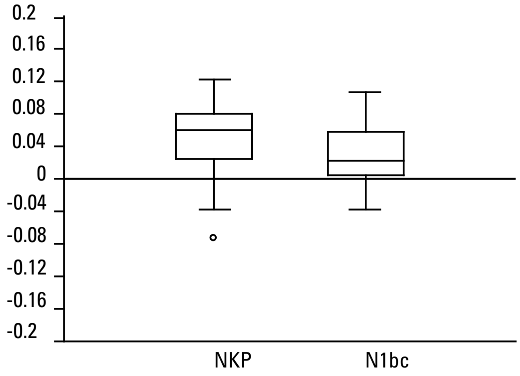

Fig. 6.34. LSI for width measurements for cattle from Early Roman military (Nijmegen-Kops Plateau) and urban (Nijmegen 1bc) Nijmegen.

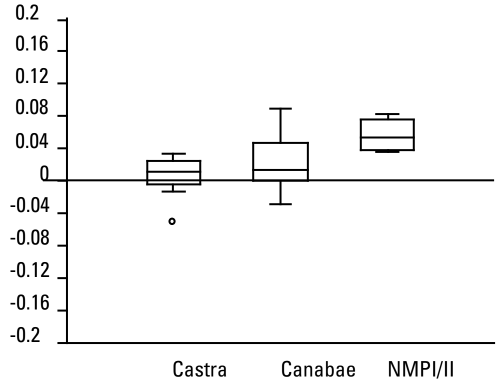

Fig. 6.35. LSI for length measurements for cattle from the *castra*, *canabae* and urban Nijmegen (Maasplein I/II).

6.6.5 ARCHAEOBOTANY

Archaeobotanical data for consumer sites were limited, but do show some interesting results. Emmer wheat and barley were found at all sites except two of the temples. Three or four sites show evidence for the imported cereals spelt and bread wheat. More exotic imports were found at four sites: olive in the Augustan camp in Nijmegen, olive, grape and fig in Nijmegen-Canisiuscollege, fig in Empel-De Werf and fig, date and pine nut in the Fortuna temple. While walnut was cultivated locally later in the Roman period, the find from Early Roman Utrecht-LR31 almost certainly represents another import. Remains of bread were found at Nijmegen-Canisiuscollege and Elst-Westeraam. These data show that at least some of the ingredients typical for a Roman diet reached the consumer sites in our research area, and some already in the early decades of occupation.

6.6.6 FOOD SUPPLY TO NIJMEGEN

6.6.6.1 Food supply of consumer sites in Early Roman Nijmegen

In the earliest period of occupation (the Augustan camp in Nijmegen), the army relied on pigs for much of their meat. The lower proportion of meat-bearing limb bones in comparison to later military sites suggests that more complete pigs were butchered in the Augustan camp. It is assumed that pigs were raised by the army rather than acquired from local farmers. In later military sites, joints of pig, perhaps preserved, were also brought to the camps. Of the cattle consumed in the Augustan camp, the high proportion of nonadults is striking. This suggests that the choice of which animals were butchered was made by the consumer rather than the producer (who would choose surplus animals, probably a mixture of young and old). This fits better with requisitioning of cattle than with other forms of acquisition. Chickens were probably kept in the camp, and supplied meat and eggs. The two assemblages have relatively high proportions of game, which could either represent a nice pastime or a necessary supplement to the diet. Roe deer and hare make up most of the numbers of game; in most other consumer sites, red deer is the most common species of game. While the presence of olive testifies to the existence of long-distance supply networks, the absence of seashells indicates that local supply networks to the North Sea had not yet been established.

A comparison of the sites Nijmegen-Kops Plateau and Nijmegen-Oppidum Batavorum/Nijmegen 1bc shows that the urban people consumed more meat other than beef than the soldiers. Pigs may have been kept in the town. A higher proportion of horse in Nijmegen-Kops Plateau can be explained by the disposal of cavalry horses outside the camp, remains of which were included in the assemblage. The differences in slaughter age and size of cattle – with the cattle from Nijmegen-Kops Plateau being generally older and larger – suggest a different supply system for the two sites. It is also possible that the two types of consumers had different requirements. The overrepresentation of fragments from the head and the higher proportion of meat-bearing limb bones suggest that parts of cattle were brought to Nijmegen-Kops Plateau. Some food was certainly supplied from outside the research area, for instance the song thrushes and chub mackerels found on the Kops Plateau (both complete fish and fish sauce), and oysters in the urban assemblages.

6.6.6.2 Food supply of consumer sites in Middle Roman Nijmegen

When studying food supply to Middle Roman Nijmegen, three different sites need to be taken into account: the Flavian *castra* and adjacent *canabae* and the town *Ulpia Noviomagus*. The earlier assemblages from the town are contemporary to the *castra* and *canabae*. There are differences in proportions of the different animals that were consumed and in the ages at which cattle were slaughtered. However, the differences do not seem strong enough to suspect completely different supply systems. Some more sheep ended up in the urban assemblages, while pork was preferred by legionaries and officers. Of the cattle supplied to Nijmegen, relatively more adult ones were consumed in the *castra*. Perhaps the army selected older animals because they were cheaper than prime-meat animals. There is also a difference in the size of cattle in the *castra* and Nijmegen-Maasplein I/II, but this can be explained by the difference in chronology. Proportions of meat-bearing limb bones for the *canabae* (75 %) and the *castra* (59 %) suggest that transport of beef on the bone to the *castra* was not significant. Game and wild birds supplemented the diet in all sites, but to a very limited degree. Finds of olive, grape and fig from the *canabae* attest to long-distance supply networks to the Mediterranean, while cereals were probably imported from the loess zone in Belgium/Northern France. Seashells were also supplied from outside the research area. Some food may have been produced inside the town of *Ulpia Noviomagus*. Evidence for this was found for the last quarter of the 1st century, where cultivated soil behind houses represents kitchen gardens.[708] Pigs and chickens may have been raised in yards behind houses, or on plots in between the habitation.[709]

[708] Willems/Van Enckevort 2009, 75.

[709] Cool 2006, 84; Hesse 2011, 219, 233; Lepetz 1996, 89.

7. Interaction between producers and consumers

The previous chapters have discussed producer and consumer sites separately; this chapter compares the results from both types of site. By comparing the data from rural and consumer sites, it is possible to investigate the hypothesis that most of the food was acquired locally. Furthermore, comparing the data will give insight into production strategies employed at the rural sites and relationships between producers and consumers. The layout of this chapter will be the same as that of the two previous chapters, looking first at species proportions and slaughter ages, then at skeletal elements, butchery methods and biometric data, and finally at archaeobotanical data. The chapter will end with a discussion and the most important conclusions with regard to developments in agriculture and food supply.

7.1 Species proportions

7.1.1 Totals per period

For each period, total numbers of fragments for the four main domesticates for all rural and consumer sites have been compared. In all periods, cattle have a higher percentage in the consumer sites; this is most noticeable in the Middle Roman period (fig. 7.1). The percentage for sheep or goat is higher in the rural sites, especially in the Early Roman period. In this period, the percentage for pig is much higher in consumer sites. In the Middle Roman period, percentages for pig are almost equal, while in the Late Roman period, the percentage is much higher in the rural sites. The percentage of horse fragments is higher in rural sites in the Early and especially the Middle Roman period, but lower in the Late Roman period. The near absence of sheep in Nijmegen-Valkhof fits in well with the low proportions of sheep in Late Roman rural sites.

7.1.2 Sheep/goat in consumer sites

The two 1st-century watchtowers in Utrecht-Leidsche Rijn both show a high proportion of sheep or goat. This was not seen in other military sites. Perhaps this is related to the small number of troops stationed at the watchtowers. Supplying them with whole cattle or parts of cattle would be more than they could eat. It is more logical to supply joints of smaller livestock and beef taken off the bone. Indeed, evidence has been found for the supply of joints of meat. However, although the proportion of sheep or goat is high, that for cattle is still higher. Fragments from the hind leg are overrepresented for both cattle and sheep/goat, so it seems that complete hind legs from both species were brought to the watchtower.[710]

A second explanation is availability. The high proportion of sheep fits in well with the 1st-century rural sites in the micro-region of Utrecht-Leidsche Rijn (fig. 7.2). Three of the five rural sites have proportions of sheep of more than 25 %. Perhaps the watchtowers were supplied by local farmers. However, some of the 1st-century rural sites in the vicinity of Nijmegen also have high proportions of

[710] Esser *et al.* 2007, 149.

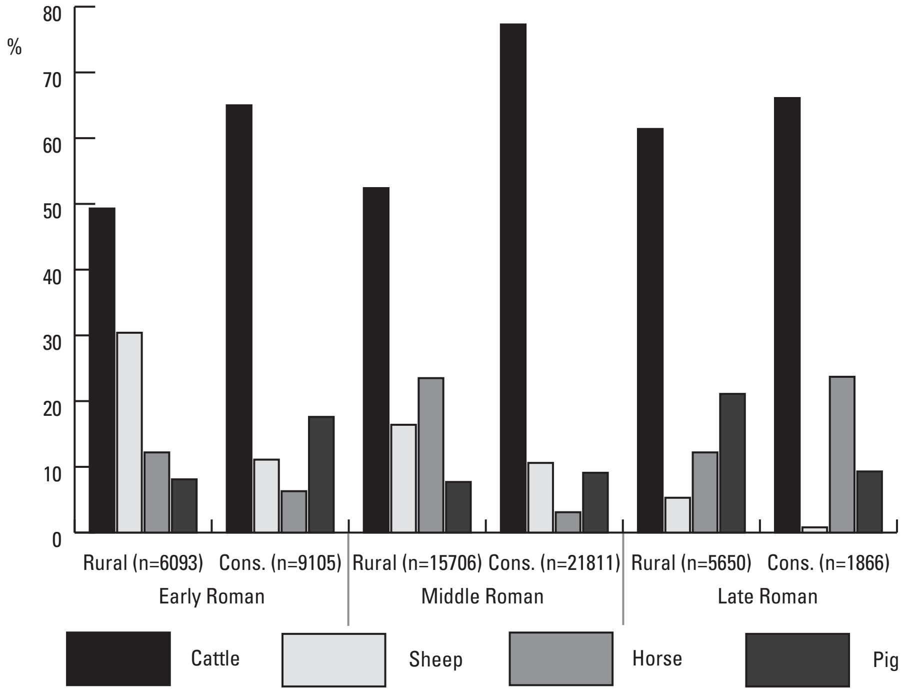

Fig. 7.1. Proportions for the main domesticates per period for rural and consumer sites, based on the number of fragments.

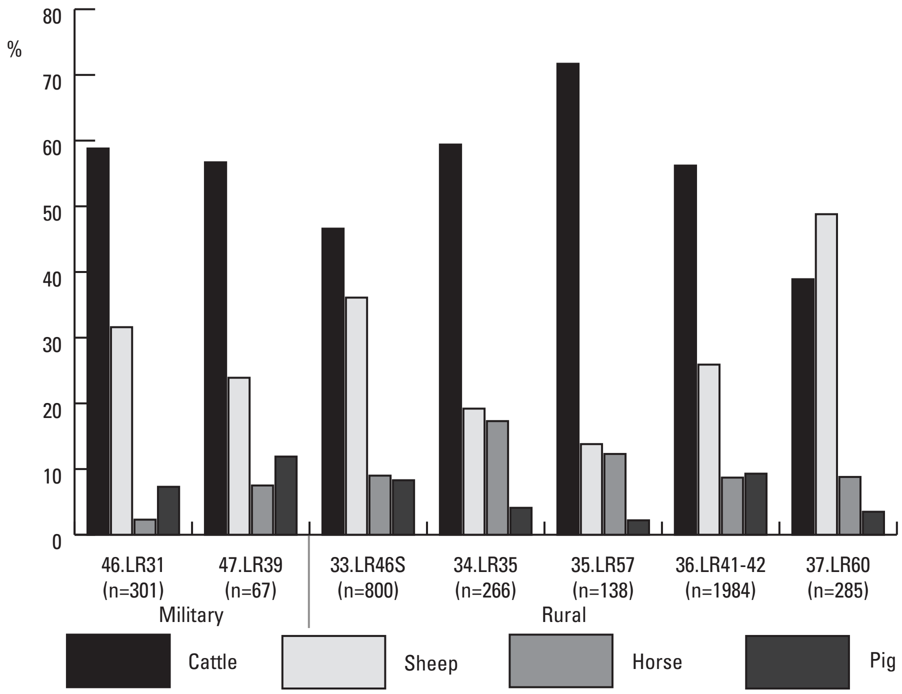

Fig. 7.2. Proportions for the main domesticates for military and rural sites in Utrecht-Leidsche Rijn, based on the number of fragments.

sheep: Ewijk-Keizershoeve 1, Lent-Petuniastraat, Lent-Steltsestraat, Oosterhout-Van Boetzelaerstraat and Arnhem-Schuytgraaf all show percentages around or above 30 %. If availability was so important, then sheep should be more important in the 1st-century consumer sites in Nijmegen. Langeveld has proposed the theory that friendly tribes from the northeastern part of the Netherlands were settled in the area Utrecht-Leidsche Rijn by the Romans in the second decade A.D. His arguments include the evidence for early contacts between the indigenous people and the army, the discontinuity in habitation between the Late Iron Age and Early Roman period, the starting date of the settlements in Utrecht-Leidsche Rijn and the pottery found in the settlements.[711] If Langeveld`s theory is true, then it would make sense that these friendly tribes would have played a role in supplying the army – or to a greater extent than the rural people in the vicinity of Nijmegen. This may explain why the high proportions of sheep in rural sites near Nijmegen are not reflected in the town and military sites in Nijmegen. On the other hand, the much larger consumer sites in Nijmegen would have required supply from a larger area than the small watchtowers.

A final explanation is the origin of the soldiers stationed in the watchtower. If they were auxiliary troops, then they may have had a taste for mutton, at least more than troops originating from Roman Italy. The diet consumed in the watchtower contains both Roman (walnut, mussels) and indigenous elements (emmer wheat, barley, sheep/goat).[712]

The urban assemblages Nijmegen-Maasplein I/II and Nijmegen-Weurtseweg 1 also show relatively high proportions of sheep/goat. In this period (c. A.D. 70-150), sheep/goat is still relatively common in the rural sites, so would certainly have been available. The question is why the species is represented better than in other consumer sites. Perhaps this has something to do with the people living in *Ulpia Noviomagus*. Some of them may either be local people or come from regions where sheep/goat is preferred as food. In both sites, a decrease in the proportion of sheep/goat occurs in the second half of the 2nd century. This decrease can be explained by the decrease in sheep/goat in the rural sites: less sheep/goat were available.

7.1.3 Proximity to consumer sites

Similarities and differences between rural sites could be related to the character of the site. However, apart from size, there are few aspects that can be used to make a division among the rural sites. We have already seen that *villae* and sites with military characteristics are not very different from other rural sites. The presence of large granaries may indicate a central function of a site, but their absence may say more about the extent of the excavation than about the nature of the site. Since the main interest of this study is the supply of food and other products from producer to consumer sites, the proximity to the *limes* or the town of Nijmegen may be the most useful way to try to explain differences in animal husbandry. The distance to a market could be highly important for farmers.

Three zones are distinguished: a '*limes*' zone, containing sites within 10 km south of the *limes*, an 'urban' zone, containing sites within a 10 km radius of Nijmegen, and a 'rural' zone, containing the rest of the sites. Of course, this completely disregards possible infrastructure in the form of roads and barriers in the form of flood basins (which may not always be accessible in winter) or rivers, but considering the lack of information on Roman roads – with the exception of the *limes* road – and even the uncertainty about the river Waal, it was the best way for this study to investigate a relationship between distance to potential markets and animal husbandry.

711 Langeveld 2010a, 324-326.

712 Van der Kamp 2007, 184-186. On the other hand, high proportions of sheep/goat have also been regarded as a preference of soldiers with a Spanish origin. Deschler-Erb 1991, 129.

What becomes immediately clear is how few of the sites included in this study are located more than 10 km away from either the *limes* or Nijmegen. Only nine sites belong to the rural zone: the two sites in Tiel-Passewaaij, Geldermalsen-Hondsgemet, the three sites in Zaltbommel-De Wildeman, Rijs & Ooyen, Brakel-Molenkampseweg and the temple Empel-De Werf. When species proportions from these sites are compared to those closer to the *limes* or Nijmegen, it becomes obvious that species proportions for most assemblages are similar to those from rural sites closer to potential markets. In a few cases, the proportion of sheep/goat is high (e.g. Tiel-Passewaaijse Hogeweg 2 and 3, Rijs & Ooyen and Brakel-Molenkampseweg), but high proportions are not restricted to these sites. It seems that the variety between individual rural settlements cannot be easily explained by their distance from potential urban and military markets. The same applies to the exploitation of livestock: differences between contemporary sites occur, but do not seem to be related to the distance from the *limes* or Nijmegen. Introduced animals and plants, such as chicken and Roman herbs, are found in all three zones, just as imported cereals and fig.

7.1.4 Supplying horses to the army

At many rural settlements in the Dutch River Area, a high percentage of horse bones is found, mainly in the 2nd and 3rd centuries. Although some horse meat was certainly consumed, this does not seem to be the main product of horses in this region. It has been suggested before that many communities in the Dutch River Area specialised in breeding and/or training horses for the Roman army.[713] The fertile flood basins were ideally suited for extensively raising horses. Horses are still kept in this way in the British New Forest, where the quality of the foals is ensured by only having approved stallions in the herd and moving them every few years to avoid inbreeding. In medieval Limburg, semi-wild herds of horses were grazed on common ground, but this practice was restricted to the elite.[714] Keeping horses extensively required little manpower. Taking into account natural mortality and replacement of breeding stock, one surplus foal could be produced for every two mares per year.[715] Foals could either be sold as yearlings or receive basic training first. The flood basins were extensive, but also used for grazing other livestock and as hay meadows. As an example, the flood basins to the south of Tiel-Passewaaijse Hogeweg covered c. 400 hectares and were surrounded by 12-15 settlements; this means that on average, each settlement had access to c. 27 hectares. Assuming that 1 hectare could support 1 large grazer, and considering the proportion of horse in Tiel-Passewaaijse Hogeweg 4 and 5-6 of 23-31 %, 6-8 horses could have been kept. These horses would have produced 2-4 surplus foals each year. Although hay meadows and flooded areas have not been taken into account in this rough calculation, fallow arable fields and fodder grown on the stream ridges, which would have supported further animals, have also been ignored. A surplus of a few horses per settlement per year does not seem much, but the density of settlements in the Middle Roman period was so high that the total for the region would have been substantial.[716]

Clearly, there was a possibility for substantial surplus production of horses, but what was the market for all these horses? This must have been the Roman army. Proportions of horse bones in military sites are low, but this can be explained by the disposal of horses outside the camps. Horse burials or dumps just outside or related to military sites are indeed present, for example in Nijmegen-Kops Plateau, Nijmegen-Schippersinternaat, and a military horse cemetery in Kesteren.[717] Horses were of course used by the Roman cavalry, but every legion also had a number of horses, used by officers and for transport

[713] Hessing 2001, 162; Laarman 1996b, 377; Roymans 1996, 82.

[714] Renes 1999, 184.

[715] Groot 2008a, 88.

[716] A number of 1000 settlements has been suggested. Vossen/Groot 2009, 96.

[717] Lauwerier/Hessing 1992; Robeerst unpublished; Van Enckevort/Zee 1996; Whittaker 2002, 142.

of goods.[718] There is no evidence for a central supply of military horses;[719] this means that army units were responsible for acquiring their own horses. Horses could be procured in different ways: by requisition, purchase from civilians or in the form of tax. Specialised stud farms also existed.[720] Hyland states that "throughout the Empire production of sufficient stock must have been a constant burden and all sources must have been tapped."[721] Horses for the army were supplied from local sources.[722]

A rough and very conservative estimate based on the number of army units stationed in the province of *Germania* shows that the number of horses in the whole province during the first three centuries A.D. ranged from around 3700 to 5300.[723] If horses really lasted on active duty for only three years, over a thousand horses were needed to replace retiring ones.[724] For the *civitas Batavorum*, between 373 and 413 horses were needed each year.[725] These could easily have been supplied by the rural settlements in the region, and would leave extra horses for export to other regions. Roman sources indicate that horses were traded over large distances in the Roman Empire.[726] On the other hand, horses would also be required for the state postal system and by urban people.[727]

7.1.5 Wild mammals, birds and fish

In the rural sites, hunting wild mammals was not significant in terms of numbers, with overall percentages per period varying from 0.5 to 2.4 %. Red deer is the most common species in all periods, in the Late Roman period followed by wild boar and beaver. However, in the Late Iron Age, Early Roman and Middle Roman periods, more than half of the red deer fragments are antler fragments, which are not evidence for hunting. In the Late Roman period, only 11 % of red deer fragments are antler.

Hunting was also uncommon in consumer sites. A difference is visible between urban and urban/military sites on the one hand and military sites on the other, with the latter showing a slightly higher percentage of wild mammals. Wild mammals were even less important in temples. In military sites, the most common species are red deer, roe deer and hare; red deer is also the main species in urban and urban/military sites.

Wild birds are more common in consumer sites (present in 76 % of sites) than in rural sites (50 % of rural sites). Ducks and geese dominate in both types of site. As mentioned in paragraph 6.6.1.7, some of these may have been kept as domestic species. Fish are also more common in consumer sites (53 % versus 32 % of rural sites). Saltwater species are mostly found in consumer sites,[728] and are evidence for trade. Pike is the most common species in rural sites.

7.1.6 Chicken and seashells

Chicken is found in less than a third of the rural sites, and always in very low percentages (< 1 % out of the total for the four main domestic mammals and chicken). This is comparable to the situation in

718 Davies 1969, 429-430; Hyland 1990, 71.

719 Davies 1969, 434-435.

720 Davies 1969, 431, 453.

721 Hyland 1990, 77.

722 Johnstone 2008, 138; Junkelmann 1990, 34.

723 These rough figures do not include horses used for transport of goods. Based on Bogaers/Rüger 1974 and Bechert/Willems 1995. Wouter Vos kindly compiled these data.

724 Hyland 1990, 86.

725 Vossen/Groot 2009, 96. These figures are based on Hyland 1990, table 2. If we use Junkelmann's figures for the number of horses per ala and a replacement rate of 25-30% per year, 480-516 horses would be required per year. Junkelmann 1991, 97-101.

726 Hyland 1990, 71.

727 Johnstone 2008, 130.

728 The only exception is a fragment of haddock from Geldermalsen-Hondsgemet.

rural sites in Britain, where 71 % of all rural sites had percentages of chicken bones lower than 1 % (but calculated out of the total for sheep or goat and chicken).[729] Rural sites in Northern France show an average proportion of 3 %, but for all domestic birds and including *villae* and *vici*.[730] Chicken is more common in consumer sites, where the species is found in about two thirds of the sites. Percentages vary from less than 1 % to 99 % in the Fortuna temple. Because of the difference in quantification, it is not possible to directly compare data from the study area with consumer sites in Roman Britain, but it can be noted that chicken is also more common in urban and military sites there.[731] The average proportion of domestic birds in urban sites in Northern France is 7 %.[732]

Seashells are found more often in consumer sites (present in 57 % of sites) than in rural sites (11 % of sites). Only one species, the oyster, is represented in the rural sites, while four species are found in consumer sites. Percentages are generally low.

7.2 EXPLOITATION OF LIVESTOCK

7.2.1 CATTLE: EPIPHYSEAL FUSION

The proportion of unfused epiphyses per period for all consumer sites together – with the exception of temples – is lower than that for all rural sites (table 7.1). This indicates that the age of the cattle consumed in rural sites is lower. Of course, any natural mortalities, which are expected to be highest in the first months of life, would occur at the rural sites where the cattle were bred, and increase the proportion of nonadults. Nevertheless, consumer sites can be expected to have a preference for younger animals, and if this was the case, it should more than compensate for the natural mortality in the rural sites. It seems that consumer sites were not consuming more younger animals than rural sites, and possibly even less.

period	rural: % unfused	rural: n total	consumer: % unfused	consumer: n total
ER	26	1071	19	531
MR	26	1762	19	2812
LR	27	863	16	323

Table 7.1. Percentage of unfused epiphyses for cattle for combined data from rural and consumer sites, per period.

The combined mortality profile for the Early Roman period shows higher slaughter rates in the rural sites in the first and third year (fig. 7.3). In the fourth year more cattle are slaughtered in the consumer sites. The proportion of adult cattle is higher in the consumer sites. In the Middle Roman period, there is very little slaughter in the first two years in the consumer sites, but relatively high slaughter rates are found in the third and fourth year, higher than in the rural sites (fig. 7.4). As a consequence, fewer adult cattle are slaughtered in the consumer sites. This differs from the result from the proportion of unfused epiphyses and the mandibular data (see paragraph 7.2.2). In the Late Roman period, slaughter rates are higher in rural sites when compared to Nijmegen-Valkhof in the first and third year and lower in the fourth year (fig. 7.5). More adult cattle were slaughtered in Nijmegen.

729 Maltby 1997, 411.

730 Chicken, goose, duck and dove. Lepetz 1996, 127-128.

731 Maltby 1997, 409-411.

732 Lepetz 1996, 127.

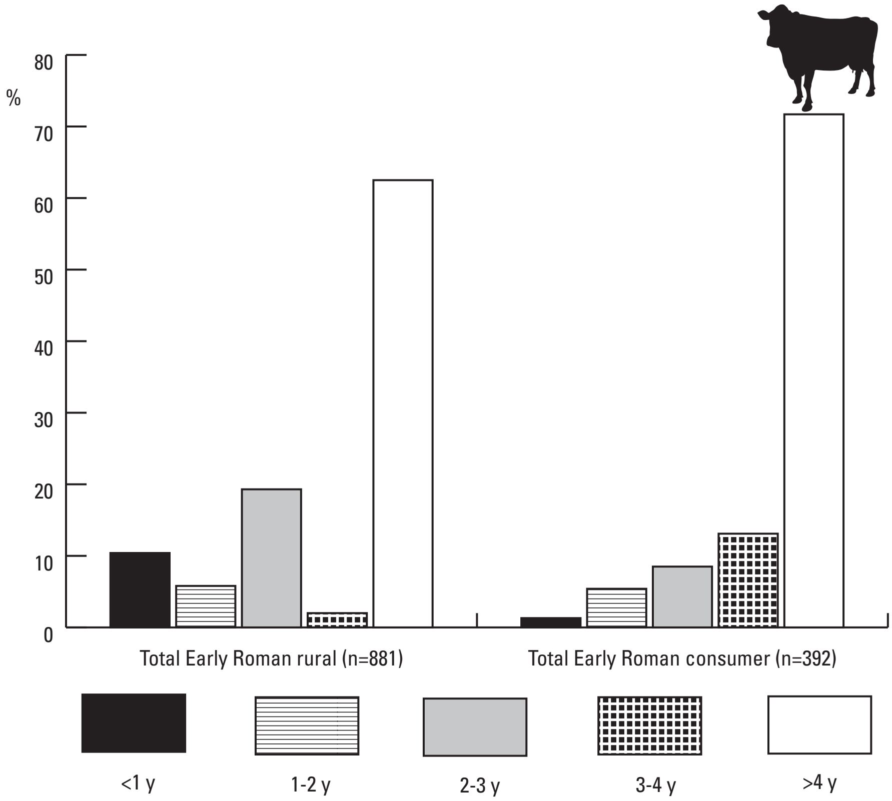

Fig. 7.3. Mortality profiles for cattle, based on epiphyseal fusion, for Early Roman rural and consumer sites. Rural sites: PHW2, HGM2, H14, LR46S and LR41-42. Consumer sites: N1bc and NKP.

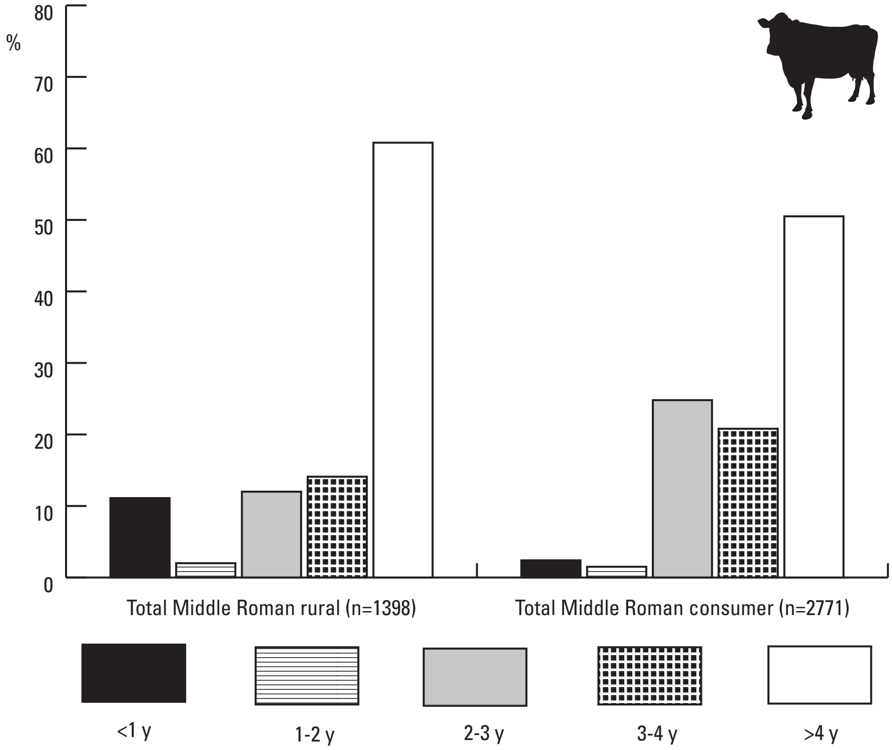

Fig. 7.4. Mortality profiles for cattle, based on epiphyseal fusion, for Middle Roman rural and consumer sites. Rural sites: PHW3, PHW4-6, OTW3, HGM3, HGM4, WDH, ZLTA, HLZD, ARS MR, DRD and DRK3. Consumer sites: NCAS, WDG1, NCL, NCW, NCC, NSS, NCT, LR58, NMP and NWW.

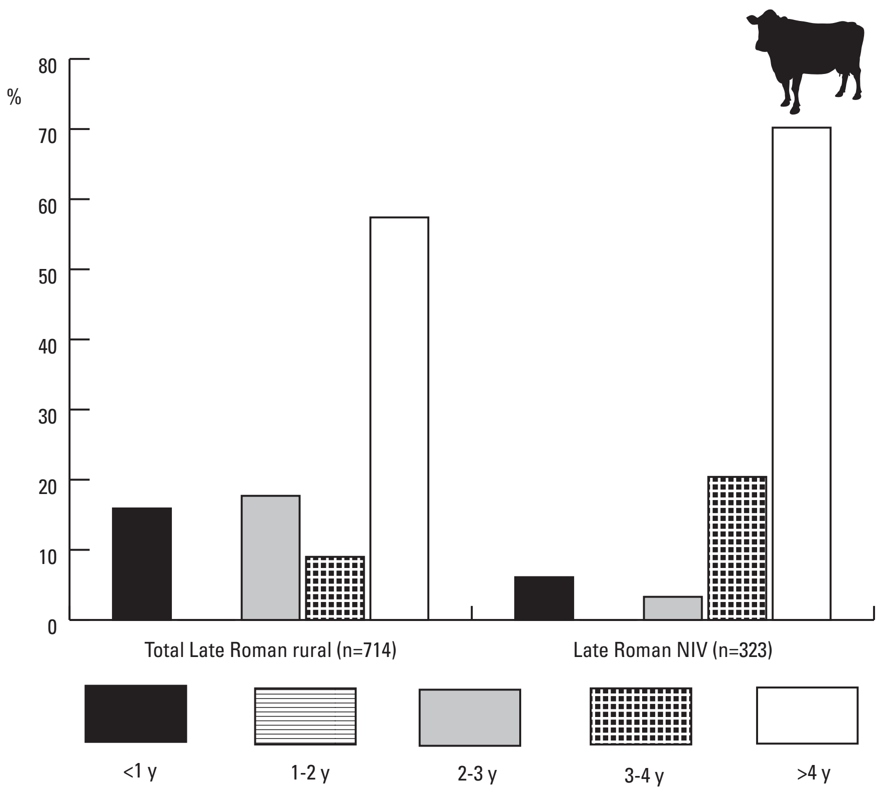

Fig. 7.5. Mortality profiles for cattle, based on epiphyseal fusion, for Late Roman rural and consumer sites. Rural sites: PHW7, OTW5, HGM5 and WDG2. Consumer sites: Nijmegen-Valkhof.

7.2.2 Cattle: mandibular tooth eruption and wear

Figure 7.6 shows mortality profiles for cattle based on mandibular age data for combined rural sites for the Early and Middle Roman period, and for several individual consumer sites. Broad age categories have been used to facilitate comparison. The increase in slaughter ages of cattle in rural sites in the Middle Roman period is clear. What is also clear is that cattle in Nijmegen-Kops Plateau, the *canabae* and Nijmegen-Weurtseweg were killed at older ages compared to the rural cattle. Two assemblages from the *canabae* and Utrecht-LR58 show higher slaughter rates between 8 and 36 months than the other consumer sites. Young calves are missing, and in that respect, both sites are typical consumer sites.[733] Nevertheless, the mortality profile for Utrecht-LR58 is not that different from that for the Middle Roman rural settlements. The temple Elst-St. Maartenstraat shows a very strong selection of cattle between 8 and 36 months (fig. 7.6). Since this is the age at which a large proportion of cattle in rural settlements are slaughtered for meat, this selection does not need to have affected rural economies to a great extent. Some cattle would be killed in this age category anyway; the only difference is that they were now killed in a different location. While consumption may have included a much larger number of people than the family owning the cow, they could expect to receive meat from other cattle killed in the temple, compensating their loss. One temple would receive cattle from a large number of rural sites, which means that the pressure on individual settlements to supply cattle may have been limited. Due to the lack of mandibular data for Nijmegen-Valkhof, no comparison of mandibular age data between rural and consumer sites could be made for the Late Roman period.

733 Although a loose tooth from a calf younger than one month was found in Utrecht-LR58. Esser 2012.

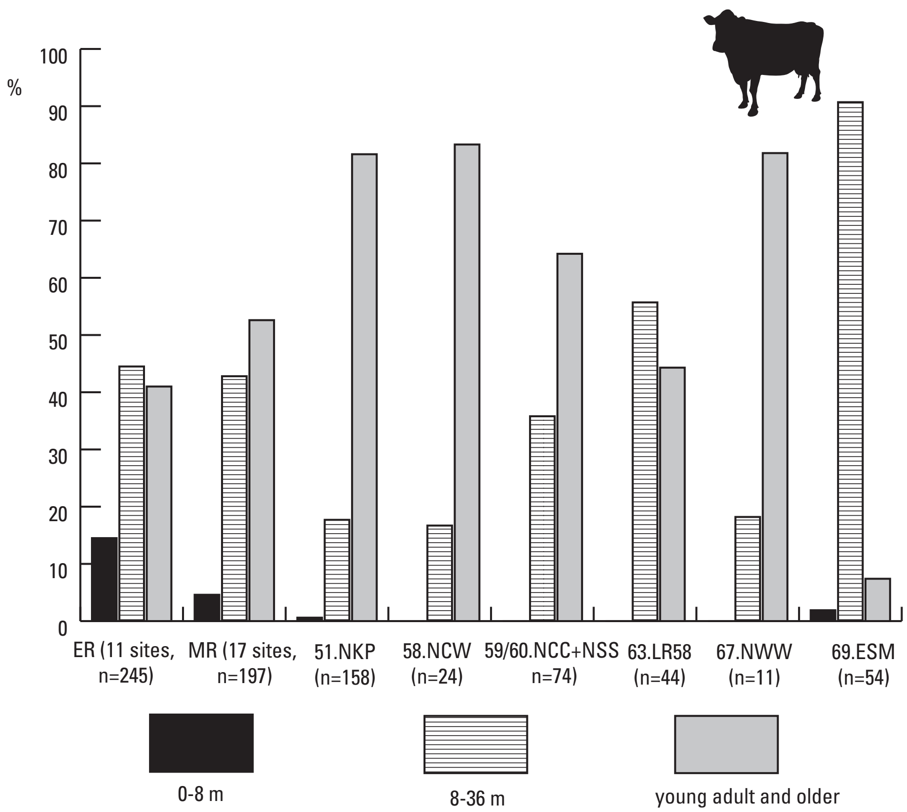

Fig. 7.6. Mortality profiles for cattle from Early and Middle Roman rural and consumer sites, based on mandibular tooth eruption and wear.

7.2.3 sheep/goat

The proportion of unfused epiphyses per period for all consumer sites together has been compared with that for the rural sites. In the Early Roman period, more young sheep are slaughtered in the rural sites, while the opposite occurs in the Middle Roman period, when more young sheep are killed in consumer sites (table 7.2). Mandibular data were only available for one consumer site – the *canabae* in Nijmegen –, where adult and old sheep outnumber younger ones. However, the sample size is small and the data give a different result from the epiphyseal fusion.

period	rural: % unfused	rural: n total	consumer: % unfused	consumer: n total
ER	47	554	34	91
MR	30	392	44	158

Table 7.2. Percentage of unfused epiphyses for sheep/goat for combined data from rural and consumer sites, per period.

In the Middle Roman period, more prime-meat animals were supplied to the consumer sites. This could mean that less mutton was consumed in the rural sites, with sheep now mainly being kept for their wool. However, the evidence for wool production in the research area is slight: the age data for rural sites may show a slight shift to wool production in the Middle Roman period, but at the same time the proportion of sheep is declining. This does not suggest an emphasis on producing wool for the army or town. If local wool production was indeed limited, then the wool needed in the consumer sites must have been supplied from elsewhere.

7.2.4 HORSE

The proportion of unfused epiphyses is lower in consumer sites than in rural sites (table 7.3). This difference increases in the Middle Roman period. The higher proportion of unfused epiphyses in rural sites is probably a result of the selling of adult horses, which causes the younger animals to be overrepresented. A second factor is natural mortality of young horses and selective culling of animals. Finally, the consumption of horse meat was much more common in rural sites.

period	rural: % unfused	rural: n total	consumer: % unfused	consumer: n total
ER	10	281	5	57
MR	20	1120	8	79
LR	36	235	16	146

Table 7.3. Percentage of unfused epiphyses for horses for combined data from rural and consumer sites, per period.

7.2.5 PIG

In the Early Roman period, the proportion of unfused epiphyses is slightly lower in consumer sites when compared to the rural sites, while it is significantly higher in the Middle Roman period (table 7.4). The rural sites show a drop in the proportion of unfused epiphyses, which could be a result of selective transport of young animals away from the settlements.

period	rural: % unfused	rural: n total	consumer: % unfused	consumer: n total
ER	63	131	58	246
MR	46	186	65	371
LR	40	357	44	48

Table 7.4. Percentage of unfused epiphyses for pigs for combined data from rural and consumer sites, per period.

The mandibular data for rural and consumer sites show the same pattern, with most slaughter taking place between 14 and 21 months, but there is more slaughter of pigs younger than 14 months in consumer sites (fig. E7.1). The mandibular data show no evidence for piglets younger than 2 months in consumer sites, which suggests that keeping and breeding pigs in consumer sites was not common. Consumer sites for which bones from foetal or neonatal pig bones are reported are the *canabae* in Nijmegen and the temple in Empel.[734] The ratio between the sexes in the Early Roman period shows a difference between the rural and consumer sites: while the sexes are represented equally in the rural sites, males dominate in the only consumer site (Nijmegen-Kops Plateau; fig. 7.7). In the Middle Roman period, the difference is much smaller, and now females outnumber males in the consumer sites.

[734] Hoek/Brinkhuizen 1990 (foetal and sucking pigs); Seijnen 1994 (one foetus and six fragments of pigs of several weeks old). Thijssen mentions 'very young pigs' for the Augustan camp, but it is unclear what this means exactly. Thijssen 1988.

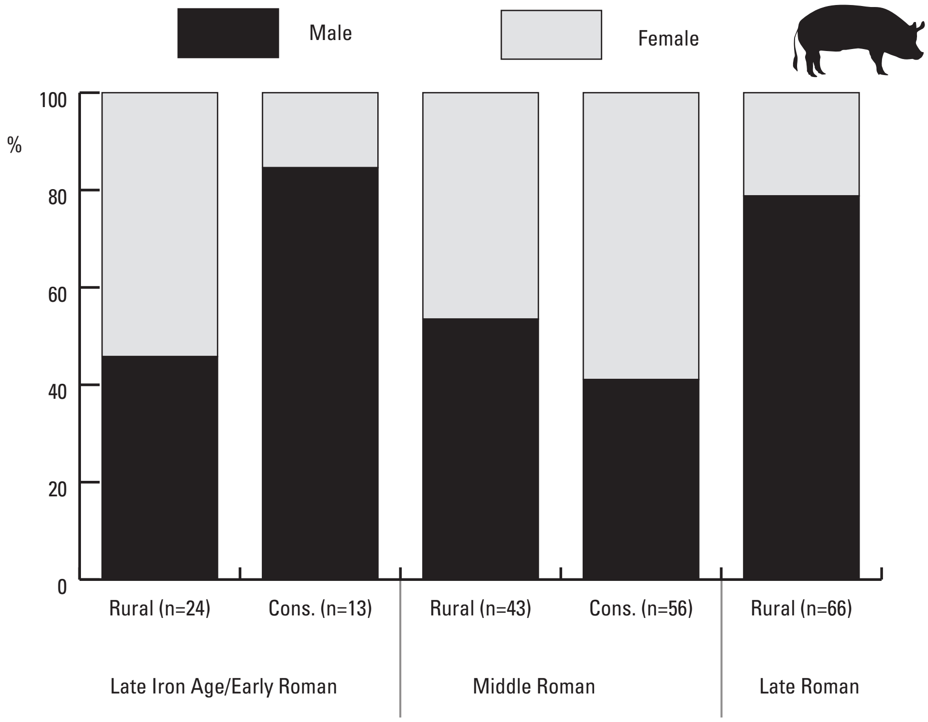

Fig. 7.7. Sex ratios for pigs from rural and consumer sites (based on the morphology of the canine teeth).

7.3 Skeletal elements: leather and joints of meat

A comparison of the distribution of skeletal elements from rural and consumer sites may reveal evidence for trade in animal products and/or cured meat. It may also reveal transport of hides to consumer sites for processing. Ratios of meat-bearing to nonmeat-bearing cattle limb bones are similar for rural and consumer sites in all periods, suggesting that cattle were primarily transported as live animals and slaughtered where they were consumed (fig. E7.2).

In the rural sites, there is a slight underrepresentation of phalanges in the Middle Roman period; small-scale production of cattle hides is therefore possible. Large-scale production is unlikely, considering that no facilities for processing hides have been found, and that any production of hides would also have resulted in large amounts of meat. Groenman-van Waateringe gives insight into the large amounts of leather required by the army, mostly from goats and needed to make tents, shield-covers, shoes, saddles etc. While goatskins were certainly not supplied from our research area, according to Groenman-van Waateringe cow hides used by the army probably came from Northwestern Europe.[735] For shoes alone, one legion would require 1500 cattle hides a year.[736] Local tanning is considered unlikely due to the scale involved and the absence of evidence for (large) tanneries in Northwestern Europe.[737] Van Driel-Murray provides some explanations for the lack of tanneries in the northwestern provinces, including a reuse of tanning waste and a possible location `deep in the countryside`, near running water and a supply of bark.[738] Nevertheless, the countryside of the research area is relatively well-known, and if tanning was practised at a large scale, it seems that some evidence of this should have been found. In Roman Switzerland, tanneries were identified on the basis of features, leather finds and tools.[739]

735 Groenman-van Waateringe 2009, 212.

736 Van Driel-Murray 2000, 63.

737 Groenman-van Waateringe 2009, 212.

738 Van Driel-Murray 2011.

739 Deschler-Erb 2012b. The features include wooden tubs.

While manufacture of leather goods used by soldiers was mostly carried out by the army – although the manufacture of shoes was turned over to civilians in the 2nd century –, Van Driel-Murray suggests that the tanning was not done by the army, but rather that tanneries were small-scale and private.[740] The rural people in the research area may have supplied cattle hides on a small scale; additionally, hides from cattle slaughtered in the town and army camps would also have been tanned. There are also indications that hides were imported from north of the border.[741] It was not just the army that had a demand for leather. People living in towns would also have required leather products such as shoes.

Archaeological evidence for tanning may be lacking, but there is some zooarchaeological evidence from the northwestern provinces. In Tongeren, a series of large pits of which some were lined with clay (for waterproofing), filled with refuse including lots of cattle horncores, was interpreted as the remains of a tannery.[742] Interestingly, this tannery was located in the centre of the Roman town. On the basis of an overrepresentation of bones from the skull, feet and tail – with one species dominating –, tanneries were identified in Augst, *Vitudurum*, Baden, *Vindonissa* and *Petinesca*, in some cases in the middle of town.[743] So far, there is no evidence for tanneries in the research area, but it would not be surprising to find this in urban Nijmegen, since only a small part of the Roman town has been excavated.

Analysis of skeletal elements from consumer sites also led to some tentative conclusions. The underrepresentation of lower limb bones of cattle in Nijmegen-Kops Plateau may be a result of the supply of joints of beef. In Utrecht-LR31, an overrepresentation of upper limb bones was also interpreted as resulting from the supply of joints of meat. In contrast, the relatively low proportion of upper limb bones and relatively high proportion of lower limb bones of cattle in Elst-Grote Kerk and Elst-St. Maartenstraat (especially in the period before the temple was built) suggests that cattle were slaughtered in the sanctuary, and some of the parts rich in meat were taken back to the rural settlements.

Evidence for consumption of smoked shoulders of beef has been found in both consumer sites and rural settlements. Evidence for production has not been found. It is possible that some small-scale production occurred in rural settlements, where shoulders could be smoked over a household fire. It is also possible that smoked shoulders were imported from regions where large-scale production has been identified, or that the evidence for production is simply missing in urban Nijmegen because relatively little of the Roman town has been excavated.

Ratios for meat-bearing and nonmeat-bearing limb bones for pig are similar for rural and consumer sites in the Early Roman period (fig. E7.3). In the Middle Roman period, the two types of site also show similar ratios, with a higher proportion of meat-bearing elements than in the Early Roman period. This could indicate import of preserved joints of meat, but this would then have been equally common in rural and consumer sites. In the Late Roman period, the proportion of meat-bearing elements is even higher in Nijmegen-Valkhof, but remains similar to that in the Middle Roman period in the rural sites.

740 Van Driel-Murray 1985, 56, 62, 64.

741 Van Driel-Murray 1985, 60-61.

742 Ervynck 2011, 110; Vanderhoeven/Ervynck 2007, 163-166.

743 Deschler-Erb 2012b.

7.4 BUTCHERY

The percentage of butchery marks on cattle bones for rural sites is 12 to 15 % on average per period (excluding the Late Iron Age). For the consumer sites, the average is much higher at 44 %; this is due to the numerical dominance of the two assemblages from the *canabae* that both show very high slaughter rates. More butchery marks would also be expected in urban sites – for which no data are available for the research area –, since cleavers were commonly used and they are more likely to leave butchery marks than knives.[744] In this respect, the *canabae* are comparable to urban sites. As we have seen, cleavers were also used in some rural sites, but presumably much less frequently than in consumer sites, where specialist butchers operated. The ratio of chop to cut marks on cattle bones is generally lower in rural sites – varying between 0.2 and 3 –, but there is overlap with the consumer sites – where it varies from 1.3 to 33. A lower ratio fits the relative scarcity of cleavers in rural settlements compared to consumer sites. In rural sites, 44-100 % of chop marks are superficial, while 0-56 % chop through bones. The two consumer sites for which this could be established fall within the range for rural sites: for Wijk bij Duurstede-De Geer, 53 % of chop marks are superficial and for Utrecht-LR58 74 %.[745] The average percentage per period for butchery marks on horse bones for rural sites is 7-10 %, while 3 % of horse bones from consumer sites have butchery marks. Horses were butchered less often in consumer sites, but this did occur occasionally.

7.5 BIOMETRICAL ANALYSIS

7.5.1 WITHERS HEIGHT

Table 7.5 shows the average withers height for cattle per period for rural and consumer sites in the research area. Only in the Late Roman period is there a real difference in average withers height, but what is interesting is that the range of withers heights is wider for the rural sites. While this can be explained for the Early and Middle Roman period by the difference in sample sizes, sample sizes for the Late Roman period are similar. The small difference in mean withers height in the Middle Roman period can be explained by an early date for most of the data from consumer sites.

	mean (cm)	n	range (cm)
Early Roman			
rural	114	68	97 – 140
consumer sites	115	19	105 – 125
Middle Roman			
rural	119	99	99 – 140
consumer sites	117	29	98 – 142
Late Roman			
rural	121	52	102 – 149
consumer sites	127	54	113 – 143

Table 7.5. Reconstructed withers height for cattle.

744 Maltby 2010, 126.

745 The animal bones from Utrecht-LR58 date to the Early and Middle Roman period and those from Wijk bij Duurstede-De Geer 1 from the latter half of the Middle Roman period. This could explain the difference in percentage of superficial chop marks; on the other hand, the nature of the habitation (*vicus* or military site) could also be a reason.

Withers heights for sheep are similar for rural and consumer sites in the Early Roman period (table 7.6). In the Middle Roman period, sheep in consumer sites are slightly larger.

	mean (cm)	n	range (cm)
Early Roman			
rural	60	19	55 – 66
consumer sites	60	12	56 – 68
Middle Roman			
rural	59	22	51 – 64
consumer sites	63	18	55 – 72

Table 7.6. Reconstructed withers height for sheep.

Horses in consumer sites are somewhat larger than in rural sites, but only in the Early and Middle Roman periods; in the Late Roman period, the opposite is the case (table 7.7).

	mean (cm)	n	range (cm)
Early Roman			
rural	133	46	121.4-153.3
consumer sites	136	9	120.8-148.4
Middle Roman			
rural	140	166	120 – 156
consumer sites	142	14	127 – 163
Late Roman			
rural	142	22	128 – 153
consumer sites	140	32	132 – 150

Table 7.7. Reconstructed withers height for horse.

7.5.2 LOG SIZE INDEX FOR CATTLE

7.5.2.1 Early Roman period

For the rural sites, data from Late Iron Age/Early Roman Tiel-Passewaaijse Hogeweg 2, Geldermalsen-Hondsgemet 2, Druten-Klepperhei 1 and Early Roman Tiel-Oude Tielseweg 2, Wijk bij Duurstede-De Horden, Utrecht-LR46S and Utrecht-LR41-42 have been pooled together. For the consumer sites, data were available for military Nijmegen-Trajanusplein and Nijmegen-Kops Plateau, urban Nijmegen 1bc and the temple Elst-St. Maartenstraat. The width, length and depth measurements all show a statistically highly significant difference between the rural sites and consumer sites: cattle in consumer sites have consistently larger measurements (figs. 7.8-10; table E7.1). To make sure that this was not an effect of including some Late Iron Age data, the consumer sites were also compared with measurements from rural sites with secure Early Roman sites. Whether or not the Late Iron Age/ Early Roman overlapping assemblages are included or not, the result is the same.

By combining all data from consumer sites, the difference between individual sites has been lost. A possible difference in the supply of cattle to Nijmegen-Kops Plateau and Nijmegen 1bc has already been discussed in paragraphs 6.6.4 and 6.6.6. To investigate the relationship between those sites and the surrounding countryside, LSI data were compared. The cattle found in Nijmegen-Kops Plateau

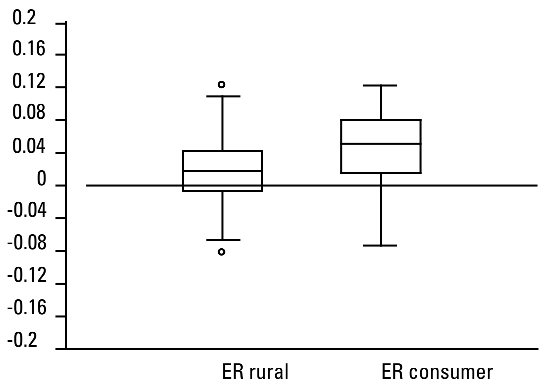

Fig. 7.8. LSI for width measurements for cattle from Early Roman rural and consumer sites.

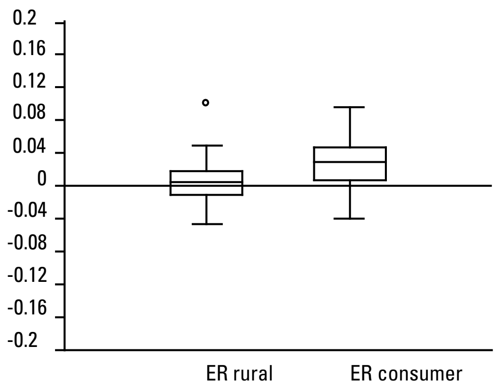

Fig. 7.9. LSI for length measurements for cattle from Early Roman rural and consumer sites.

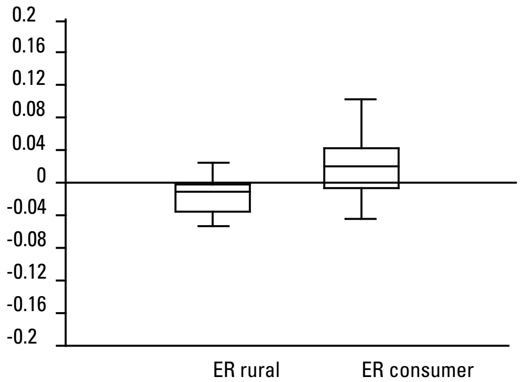

Fig. 7.10. LSI for depth measurements for cattle from Early Roman rural and consumer sites.

are larger than those in the rural settlements, with a statistically highly significant difference in all dimensions (figs. 7.11-13; table E7.2). The cattle in urban Nijmegen 1bc are larger than those in the rural sites (although this is only statistically significant for depth measurements) and smaller than those in Nijmegen-Kops Plateau (although only statistically significant for width measurements).

There are several possible explanations for the difference in size. First, it is possible that the cattle supplied to Nijmegen-Kops Plateau did not come from the research area at all. Alternatively, supply was organised more locally, and did not include the western part of the research area, where most of the data come from. There may have been a regional difference in cattle size, with larger cattle in the direct vicinity of Nijmegen. What is needed are Early Roman data from rural sites closer to Nijmegen. Second, there could have been a selection of larger animals, perhaps an overrepresentation of adult males, for Nijmegen-Kops Plateau. In the rural settlements, cows dominate, but it is not clear what the sex ratio was in Nijmegen-Kops Plateau or in urban Nijmegen 1bc. Whittaker used the proximal breadth of the metatarsus to investigate the reason behind the size increase in cattle observed in the withers heights.[746] He found a bimodal distribution in Nijmegen-Kops Plateau and explained this by sexual dimorphism. Since he used very few measurements for his comparison with the Late Iron Age/Early Roman rural cattle, I have plotted the same measurement for Late Iron Age and Early Roman sites, together with those from Nijmegen-Kops Plateau and Nijmegen 1bc (fig. E7.4).[747] What is clear is that there is complete overlap between the rural sites and Nijmegen-Kops

746 Whittaker 2002, 230-234.

747 Proximal breadth measurements were used to allow a comparison with Whittaker's results, but it needs be born in mind that this measurement is age-dependent, and – unlike with articulations with epiphyses – it is not possible to differentiate between adult and non-adult animals.

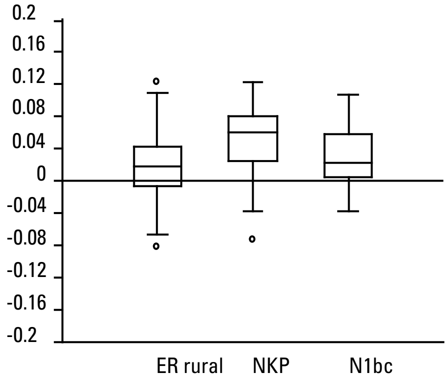

Fig. 7.11. LSI for width measurements for cattle from Early Roman rural sites, Nijmegen-Kops Plateau and Nijmegen 1bc.

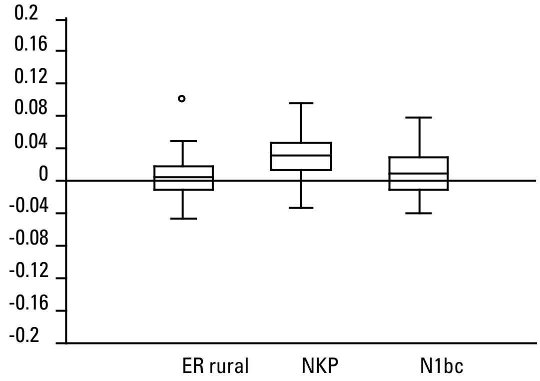

Fig. 7.12. LSI for length measurements for cattle from Early Roman rural sites, Nijmegen-Kops Plateau and Nijmegen 1bc.

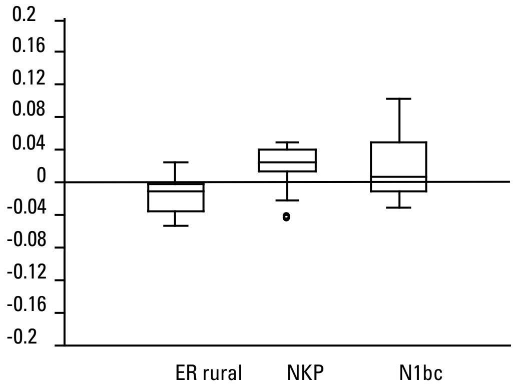

Fig. 7.13. LSI for depth measurements for cattle from Early Roman rural sites, Nijmegen-Kops Plateau and Nijmegen 1bc.

Plateau. The rural sites do not show a bimodal distribution (perhaps the Late Iron Age data do, but the difference between the two peaks is much smaller than that in Nijmegen-Kops Plateau). However, it was seen earlier that there is a size increase in the rural sites in the Early Roman period.[748] Since this cannot be explained by sexual dimorphism, it is likely that it was caused by early imports of larger cattle. These cattle were supplied through army channels to Nijmegen-Kops Plateau, but some ended up in urban Nijmegen 1bc, and fewer in the rural settlements. The fort in Nijmegen was not only supplied with imported cattle, but also with local cattle from the surrounding countryside. Local cattle formed a more important source for the early town. This would explain why cattle are largest in Nijmegen-Kops Plateau and smallest in the rural sites, why there is complete overlap in the metatarsal proximal breadth measurements, and finally it also explains the bimodal distribution, with the larger peak consisting of large, imported cattle. Cattle of a similar size are found in Early Roman but not in Late Iron Age sites. By the way, the LSI data for Nijmegen-Kops Plateau do not show a bimodal distribution, although a slight skew to the right is visible in the width measurements (fig. E7.5).

While the measurements suggest the import of cattle to supply Nijmegen-Kops Plateau and to a lesser extent the early town of Nijmegen, and the age data suggest a difference in slaughter ages between these sites and the rural settlements,[749] there is other evidence that suggests that the cattle in Early Roman Nijmegen belong to the same population as the rural cattle. In paragraph 5.9.9.1, the prevalence of non-metric traits was used to suggest a genetic change in cattle during the Roman

[748] See paragraph 5.7.2.1.

[749] See figs. 7.6 and 7.11-13.

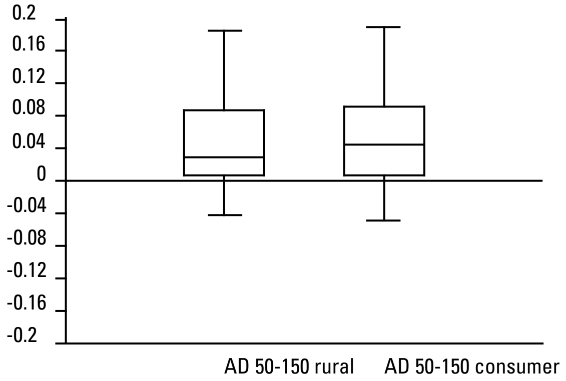

Fig. 7.14. LSI for width measurements for cattle from rural and consumer sites dating to the period A.D. 50-150.

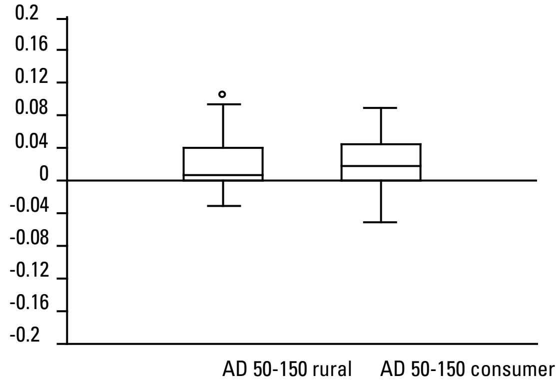

Fig. 7.15. LSI for length measurements for cattle from rural and consumer sites dating to the period A.D. 50-150.

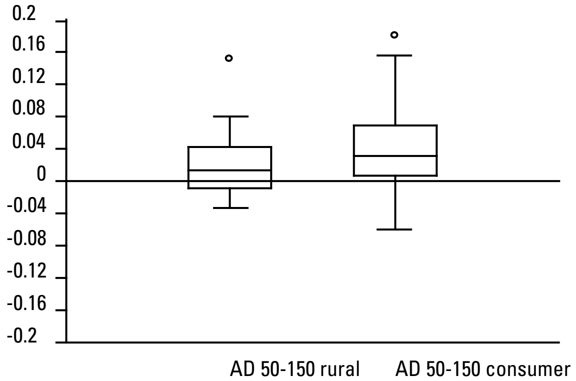

Fig. 7.16. LSI for depth measurements for cattle from rural and consumer sites dating to the period A.D. 50-150.

period. The prevalence of an abnormal lower third molar in cattle (missing hypoconulid) is 6 % for Late Iron Age sites, and 12.5 % for Roman rural sites (table 5.10). For Nijmegen-Kops Plateau, prevalence is 6.5 % and thus similar to the Late Iron Age indigenous cattle. For the *canabae*, which have a later date than Nijmegen-Kops Plateau, prevalence is higher at 9 %.[750] This would suggest that the influx of new genetic material did not take place, or had little effect, in the Early Roman period. Of course, as long as we do not know the source of the cattle that were imported in the Early Roman period, we cannot be certain that the prevalence of the missing hypoconulid was not the same. It is possible that there were several distinct phases of importing cattle from different populations. All we can say at the moment is that it seems that Nijmegen-Kops Plateau had a mixed supply of local and imported cattle, and that some of the imported cattle interbred with the local population.

7.5.2.2 Middle Roman period

Combined data from five to 13 rural sites (with ten to 18 assemblages) from the Middle Roman period were compared with combined data from five to nine consumer sites (with eight to 11 assemblages). Width measurements show a statistically significant difference, while there is a statistically highly significant difference in length measurements (figs. E7.6-7; table E7.3). The measurements from cattle in consumer sites are smaller in all dimensions, but the difference in depth is not significant (fig. E7.8).

It was suspected that the differences are caused by a difference in dating of the assemblages, with assemblages dating to the early part of the Middle Roman period dominating the consumer data,

[750] Whittaker 2002, 124.

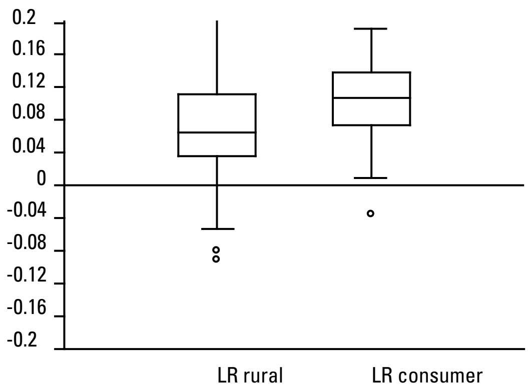

Fig. 7.17. LSI for width measurements for cattle from Late Roman rural and consumer sites.

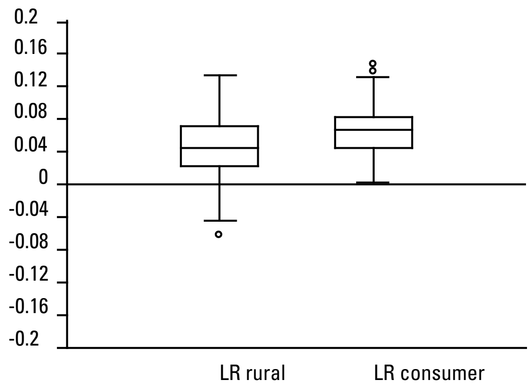

Fig. 7.18. LSI for length measurements for cattle from Late Roman rural and consumer sites.

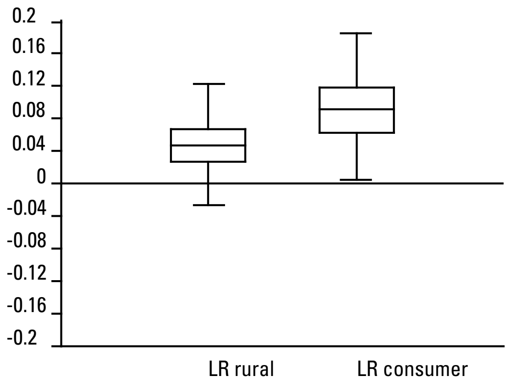

Fig. 7.19. LSI for depth measurements for cattle from Late Roman rural and consumer sites.

while the rural data are spread more evenly over the Middle Roman period. To test this, data from the *castra* and *canabae* in Nijmegen and urban Nijmegen-Maasplein I/II (all dating to A.D. 70-150 or shorter periods within that timeframe) were compared with rural assemblages dating to the period A.D. 50-150 (Tiel-Passewaaijse Hogeweg 3, Tiel-Oude Tielseweg 3, Geldermalsen-Hondsgemet 3 and Druten-Klepperhei 2). No significant differences were present between the data sets (figs. 7.14-16; table E7.4). This means that the cattle slaughtered in the consumer sites could have come from the rural sites included in the analysis.

7.5.2.3 Late Roman period

Data from seven rural sites were compared with those from Late Roman Nijmegen-Valkhof. Cattle from the latter site are larger in all dimensions, and the differences are statistically highly significant (figs. 7.17-19; table E7.5). This suggests that the cattle consumed in Late Roman Nijmegen were not supplied by the rural sites included in this study.

7.6 ARCHAEOBOTANY

Interaction between rural and consumer sites would not just have focused on animal products, but also on crops. A comparison between archaeobotanical data from rural and consumer sites can give some insight into the supply of plant foods. Unfortunately, the number of assemblages from consumer sites is especially small, so the conclusions reached below are tentative in most cases.

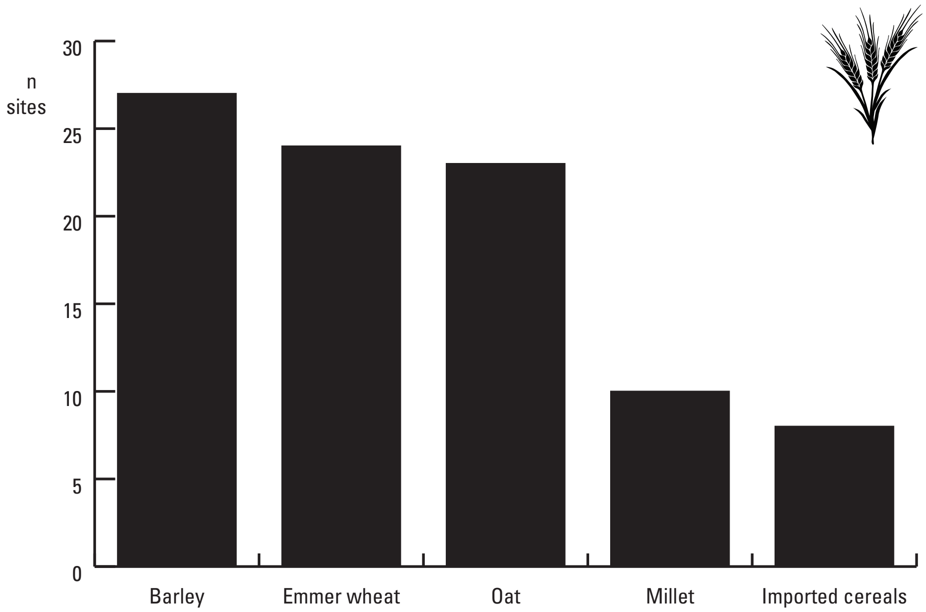

Fig. 7.20. Occurrence of cereals in rural sites: number of sites where cereals are present.

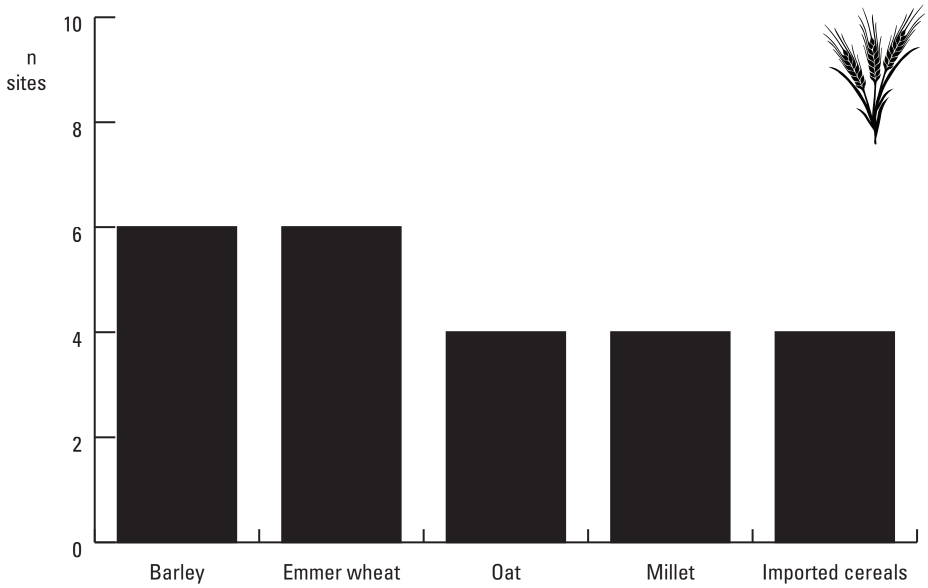

Fig. 7.21. Occurrence of cereals in consumer sites: number of sites where cereals are present.

The cereals that are most common in the rural sites, and were grown by the farmers there, are barley, emmer wheat and oat. These cereals are also found in the consumer sites. It is therefore possible that some of the cereals were supplied by local farmers. In some rural sites, large granaries are found with a capacity that exceeds the local needs; this is taken as an indication that these sites produced a surplus of cereals for the Roman market.[751] While evidence for imported cereals (kernels of spelt and bread wheat and exotic weeds) are found in some rural sites, they are much more common in the consumer sites (figs. 7.20 and 7.21). Millet is also found more commonly in consumer sites, but was

[751] Groot *et al.* 2009.

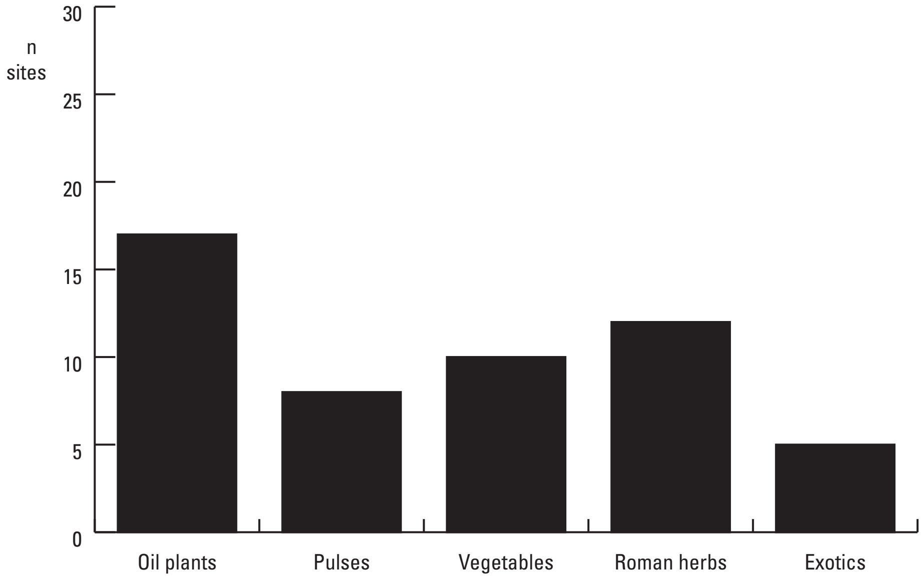

Fig. 7.22. Occurrence of other crops in rural sites: number of sites where other crops are present.

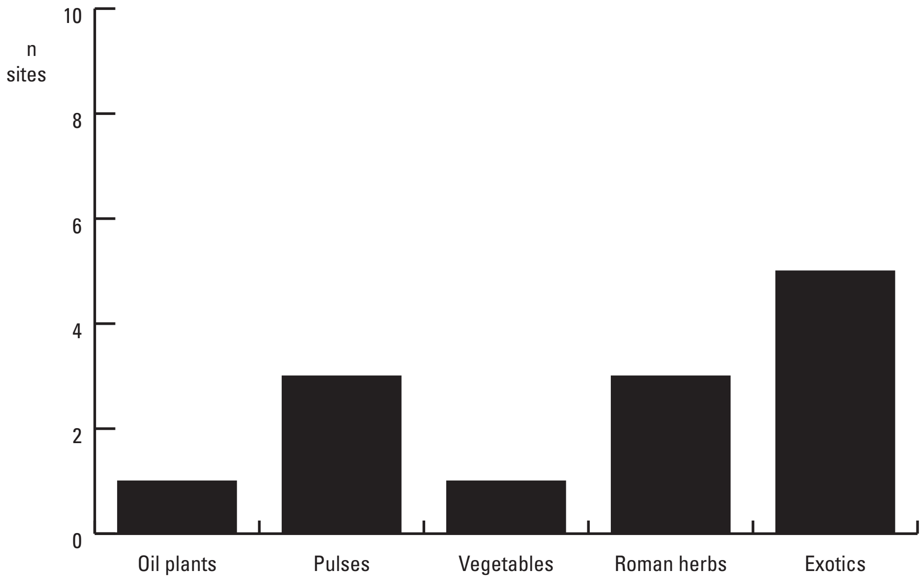

Fig. 7.23. Occurrence of other crops in consumer sites: number of sites where other crops are present.

probably grown locally. Cereals imported from outside the research area reached some of the rural sites. It is likely that they were acquired in the consumer sites. This means that food was not just supplied from the rural settlements to the consumer sites, but that some food went in the other direction.

Oil plants (flax, rape and gold-of-pleasure) are almost absent in consumer sites (fig. 7.23).[752] However, this is not so surprising. If they were indeed grown for their oil-rich seeds, then the oil may have been pressed locally, which means that the seeds never travelled beyond their production site. Flax may also have been grown for the fibrous stems. Even if the stems were harvested with the seeds,

752 There is a taphonomic reason why oil plants are generally underrepresented: plant macro-remains are often preserved when they are carbonised, but because they are so rich in oil, seeds of flax, rape and gold-of-pleasure burn completely.

then the seeds would end up where the flax is processed. Such activities may have taken place in other parts of a site than consumption, and refuse may also have ended up in a different location. In the research area, flax is mostly found in low numbers, and is therefore less likely to have been grown as a surplus product.[753] If rape was grown as a leaf vegetable, then it would have been harvested before setting seed, and the crop would not leave any traces.

Pulses and vegetables are likely to be underrepresented in the archaeobotanical record, since they are not preserved well.[754] They are found in both rural and consumer sites (figs. 7.22-23). Like cereals, dried pulses can be stored for a long time and may therefore have been transported over longer distances. However, there is no evidence for this, so the pulses consumed in the town and army camps may also have been grown locally. The near lack of vegetables in consumer sites can be ascribed to the part of the plant that is consumed as food: the leaves leave no archaeological trace, while tubers can be preserved but only when they are carbonised.[755] Furthermore, most of the crop would have been harvested before the seeds developed. The seeds will only be found at the site where the plants were cultivated.[756]

Roman herbs are found in both consumer and rural sites, while exotic imports are more common in consumer sites (figs. 7.22-23). For the rural sites, the only exotic import is walnut, which was probably introduced and then grown locally during the Roman period.[757] Bread, a typical Roman product, has been found in one rural site and two consumer sites.

7.7 DISCUSSION

7.7.1 FIRST OCCUPATION: 12 B.C. – A.D. 70

7.7.1.1 Agriculture

When the Roman army first settled in the region, they encountered an agrarian economy that was mostly self-sufficient. Barley and emmer wheat provided the bulk of the plant foods that were consumed.[758] Mixed farming combined the growing of cereals and other crops with animal husbandry. Animal husbandry had a strong focus on cattle (fig. 7.24), and herds were probably larger than necessary for survival, since cattle were used not just for meat and secondary products, but also as exchange items.[759] Sheep were the second species. While cattle were mostly valued as living animals and exploited for secondary products, sheep were primarily kept for their meat.[760] Horses and pigs were kept as well, but were of less importance numerically.

The Early Roman period saw an increase in sheep, at the expense of cattle (figs. E7.9 and 7.25). Since species proportions are relative and interdependent, an increase in sheep (combined with a much smaller increase in horse) could be explained by the removal of cattle and to a much lesser extent pigs – the proportion of the latter remains stable – to the military and urban sites. Alternatively, it could mean an increased emphasis on sheep. With their faster reproduction in comparison

753 Groot/Kooistra 2009.

754 Groot/Kooistra 2009.

755 Requiring a scanning electron microscope for determination. In the Netherlands, this is only done by BIAX Consult, Zaandam. Personal communication Laura Kooistra.

756 In the case of beet, perianths have been found in some rural sites and also indicate local cultivation. Groot/Kooistra 2009.

757 Bakels/Jacomet 2003, 555; Van der Veen *et al.* 2008, 32-33. Fig is found in very small quantities and this – considering the vast number of seeds in one fig – means that it cannot be taken too seriously. Personal communication Laura Kooistra.

758 Kooistra 2009, 223.

759 Roymans 1999; Van Dijk/Groot 2013.

760 Van Dijk/Groot 2013, 181-182, 184.

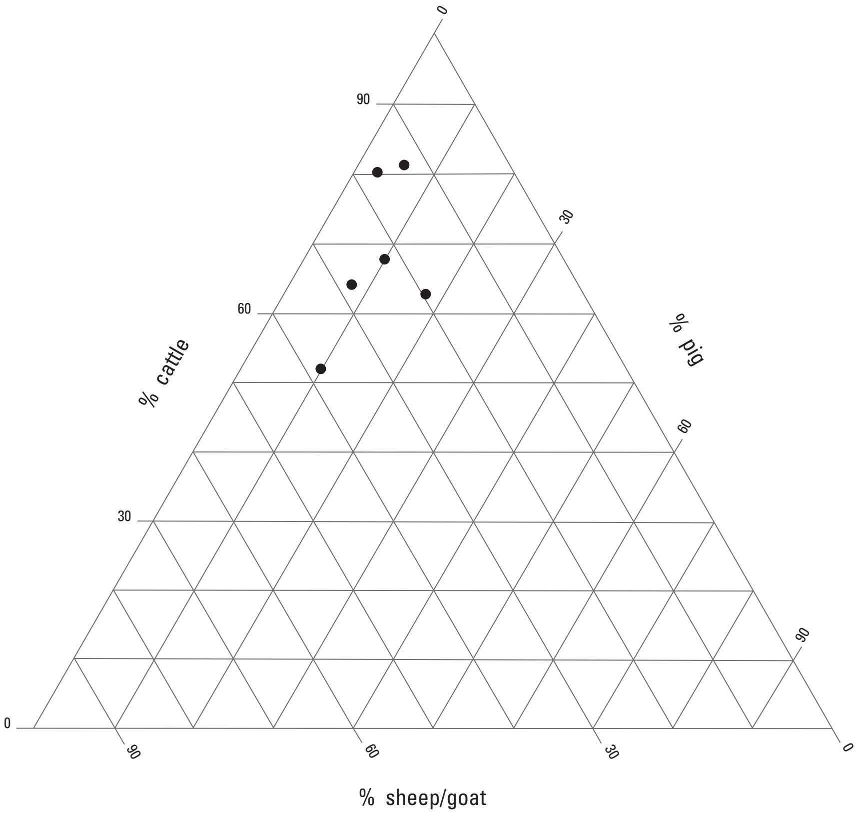

Fig. 7.24. Triplot showing the proportions for the main meat providers cattle, sheep and pig for Late Iron Age rural settlements in the river area.

to cattle, breeding surplus sheep could be a quick way to provide meat for the new markets. One military site does indeed show a high proportion of sheep, e.g. the watchtower in Utrecht-Leidsche Rijn, but in the other Early Roman military and urban sites, sheep seems to have been of little importance. An increased demand for wool could also explain an increase in sheep.[761]

Exploitation of livestock shifts to an increased emphasis on meat production of cattle.[762] No changes were observed in exploitation of the other species. The average withers heights of cattle, sheep and horse all increase in the Early Roman period.[763] LSI data also show a size increase in cattle, but only in width and length measurements.[764] The size increase in cattle can be related to the spread of imported cattle from military Nijmegen-Kops Plateau – perhaps through the early town of Nijmegen – to the countryside. While surplus cattle were supplied to the army and town, some livestock went the other way, perhaps in a deliberate attempt to influence the local population. What we cannot establish is who was behind this attempt. Was it local farmers desiring larger cattle – more meat per animal, but also more suited for traction – or the Roman army or administration trying to change local cattle to a larger type that they preferred?

Kooistra suggests that some of the cereals found in military sites in the region could have been supplied by local farmers; this is most likely for millet and oat, but also possible for barley and emmer wheat. However, local supply cannot be proven for the Early Roman period.[765]

A good deal of variety in animal husbandry in rural settlements existed, as reflected by the species proportions. Most of the variety lies in the relative proportions of cattle and sheep, but one settlement distinguished itself by a high proportion of horse. A few settlements close to Nijmegen have higher

761 However, age data for sheep from rural sites do not show an emphasis on wool production until the Middle Roman period, and even then the evidence is slight. See paragraph 7.2.3.

762 Van Dijk/Groot 2013, 184.

763 See paragraph 5.7.1.

764 See paragraph 5.7.2.1.

765 Kooistra 2009, 227.

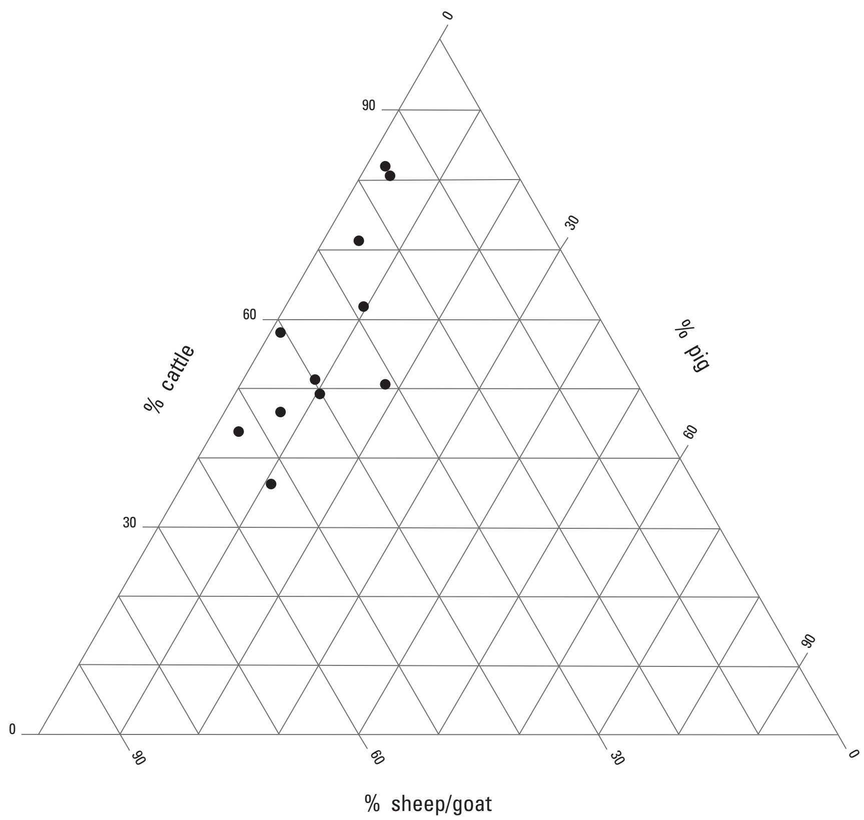

Fig. 7.25. Triplot showing the proportions for the main meat providers cattle, sheep and pig for Early Roman rural settlements in the river area.

proportions of pig, which could reflect a focus on breeding pigs for the urban and military markets. Variety was also seen in the exploitation of sheep, with some settlements focusing more on wool than others. This variety suggests that local farmers had a large say in how they practised farming; otherwise we would expect a more uniform picture. This is also suggested by the high slaughter ages of cattle in military and urban sites. Surely consumers would prefer meat of younger animals, if only the farmers would be willing or able to supply this.

It would have taken time for farmers to adjust to the new economic system. It is not easy to change traditional ways of animal husbandry, especially when livestock formed part of social systems too. The increase in cattle size can be seen as an indication that cattle lost their traditional role as a medium of gift exchange.[766] Although some changes in farming are visible, the change in mindset was probably more significant for the farmers in the region. Animal husbandry mostly continued in the way it had been practised in the Late Iron Age, but surplus cattle were now supplied to the urban and military markets, rather than staying within the herds. Some surplus cereals may also have been supplied. However, the real changes in farming come later.

Evidence for early contacts with the Roman army are found in Utrecht-Leidsche Rijn. Here, finds consisting of pottery, *militaria*, glass and coins dating to the pre-Claudian period have been found.[767] The larger cattle found here could fit within this context.[768] It is probably also not a coincidence that early finds of imported or introduced plant species are only found in a settlement in this area: Utrecht-LR46S.[769] Other settlements have also yielded imported material culture dating to the first

[766] Roymans 1996, 48; 1999, 296. The small size of Late Iron Age cattle should then not be understood as a disadvantage, caused by bad nutrition or lack of knowledge about good animal husbandry and breeding, but as a desire for quantity rather than quality.

[767] Langeveld 2010a, 324.

[768] See paragraph 5.9.9.2.

[769] Spelt wheat, coriander and weeds indicating imported cereals. The coriander predates the building of the nearby *castellum*.

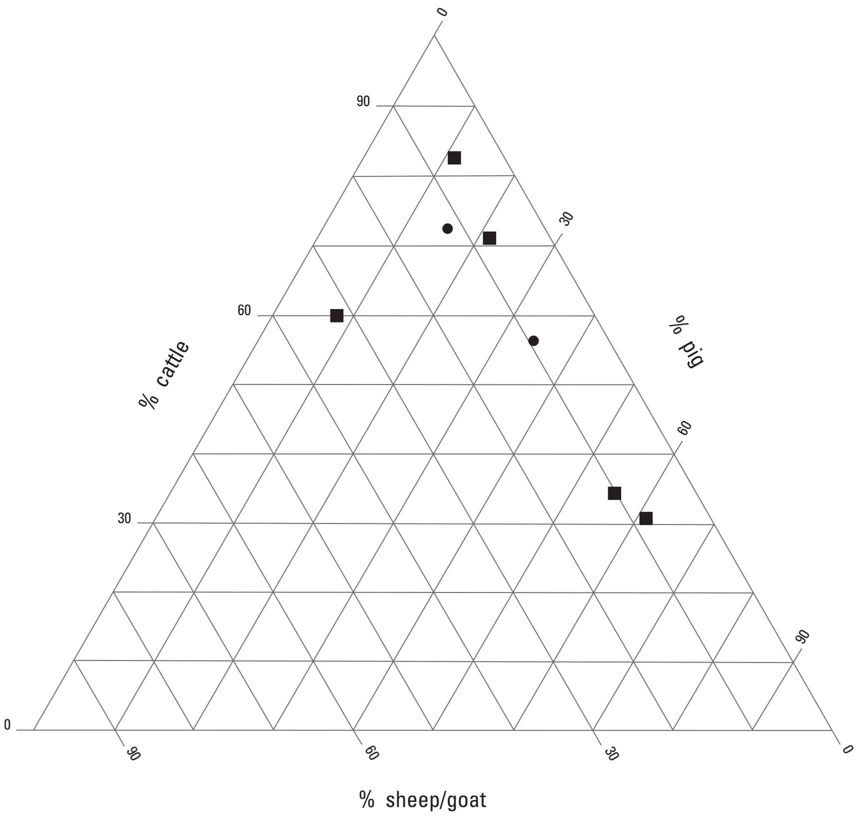

Fig. 7.26. Triplot showing the proportions for the main meat providers cattle, sheep and pig for Early Roman consumer sites (with the exception of temples). Circles: urban Nijmegen; squares: military sites.

half of the 1st century A.D. There are three explanations for the presence of Roman material culture, large cattle and imported plants in early rural settlements: diplomatic relations, trade or veterans from the Roman army, returning to their native villages.[770]

7.7.1.2 Food supply to army and town

The river landscape was not suitable for large-scale production of the 'Roman' cereals bread and spelt wheat. Large-scale breeding of pigs was not part of the local animal husbandry tradition. Furthermore, growing fodder for stabled pigs would compete with growing food for people. This means that supply of the staples of the typical Roman diet could not be supplied from local sources. So how did the Roman army and the inhabitants of the town of Nijmegen cope with this situation?

Urbanisation did not start in the region until the Roman occupation, and there was no system of surplus production for a market. The earliest military occupation was largely dependent on its own food sources (pigs), which may have been supplemented by cattle from the region (fig. 7.26). The age structure of cattle suggests forceful requisitioning, with a large proportion of young cattle. On the other hand, it is also possible that cattle were supplied from a region further away, where the emphasis was on meat production. The lack of measurements for the Augustan camp is unfortunate, as that would have been a way to prove a local or nonlocal origin of the cattle. The species proportions in the Augustan camp are similar to those found in Dangstetten (15-9 B.C.).[771] This reflects a common strategy of supply used by the army in this period.[772]

In the later Early Roman military sites, the supply system was different. Species proportions show an adaptation to local availability, with beef dominating the meat part of the diet (fig. 7.26). A watchtower in

[770] E.g. Tiel-Passewaaijse Hogeweg, Wijk bij Duurstede-De Horden and Geldermalsen-Hondsgemet. Heeren 2009, 105, 163-164; Vos 2009, 204; Van Kerckhove 2009, 155-156.

[771] Uerpmann 1977.

[772] See also Deschler-Erb/Groot in press.

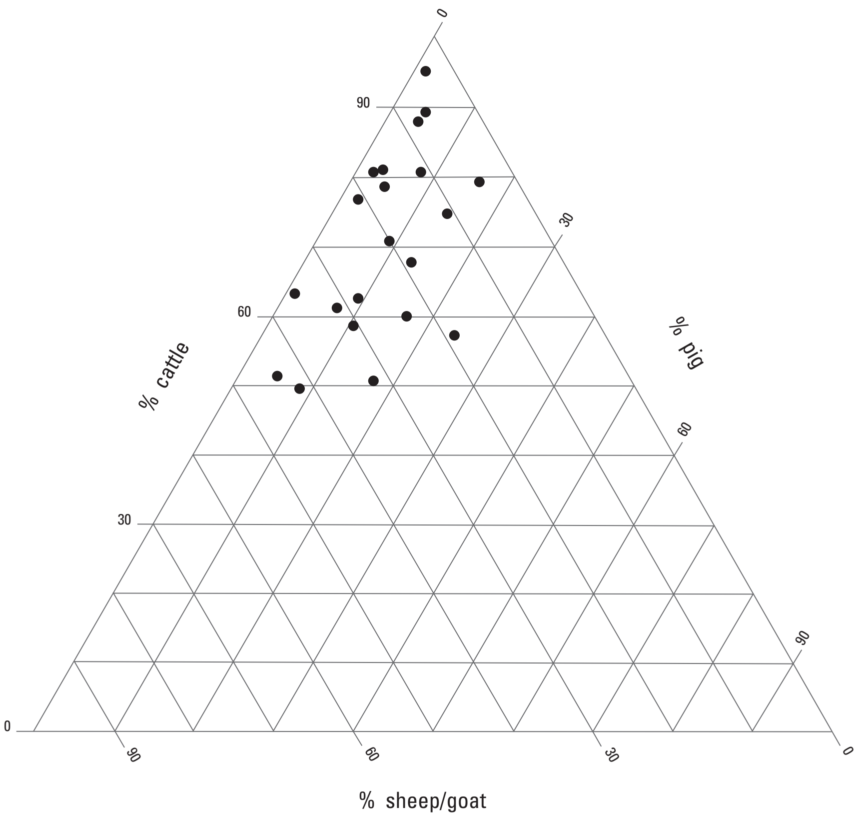

Fig. 7.27. Triplot showing the proportions for the main meat providers cattle, sheep and pig for Middle Roman rural settlements.

Utrecht shows a rather high proportion of sheep, which was also found in rural settlements in the region, and can thus be seen as an indication for local supply. In Nijmegen-Kops Plateau, cattle seem to have been imported as well as supplied from local sources. A dominance of cattle was also found in Early Roman Nijmegen. Although local farmers were not used to producing a surplus for the market, it was possible to take advantage of the cattle herds, which are likely to have been larger than required for herd survival.

The only archaeobotanical data for this period come from two military sites,[773] and provide evidence for the import of some foods, such as olive, walnut and possibly spelt wheat. The other cereals could have been grown locally, but it is likely that emmer wheat was imported from a different region.

In conclusion, food supply to the army shifted from self-sufficiency with perhaps some requisitioning to a greater reliance on local supply, although cattle were also imported. With the increase of local supply came the need to adapt to what was available, both in terms of meat animals and cereals. The town of Nijmegen seems to have relied more on local supply of cattle than the contemporary military site.

7.7.2 Local supply: Middle Roman period

7.7.2.1 Agriculture

This period sees a strong decline in sheep in the rural settlements (figs. E7.10 and 7.27). The proportion of cattle also increases slightly, while there is little change in the proportion of pig. Exploitation of sheep shows a slight shift to wool in the Middle Roman period, and a decrease in the variability observed for the Early Roman period. A drop in the proportion of unfused epiphyses for pig – in combination with a larger proportion of young pigs in consumer sites – suggests an intensification of pork production, although it is likely that this remained small in scale. The average withers heights of cattle and horse

[773] Nijmegen-Augustan camp and Utrecht-LR31.

continue to increase, but not that of sheep. Small-scale production of cattle hides may have taken place in this period. Analysis of butchery marks has shown an increase in chop marks compared to cut marks, for the region as a whole and for the settlement Geldermalsen-Hondsgemet. This is a reflection of the spread of new tools; cleavers were found in four rural settlements. Although a change in butchery technique is visible in the rural sites, it does not come close to that seen in Roman towns. The reason for this is that there were no specialist butchers in rural sites, and the processing of cattle carcasses was small-scale.

The most significant changes in animal husbandry seem to take part in the middle of the 2nd century A.D. The first is the increase in horse (figs. 5.6 and 5.10). While some settlements already show high proportions of horse before A.D. 150, and sites with a good chronology show an early, gradual increase, it is not until after A.D. 150 that horse reaches a high significance in the region. This new emphasis on horse breeding is not the only development that takes place around this time. An increase in slaughter ages of cattle, with a higher proportion of animals surviving into adulthood, started gradually but becomes most pronounced around the middle of the 2nd century. The comparison with slaughter ages in consumer sites shows that this cannot be explained by a selection of younger cattle for the market, which was one of the two explanations offered in paragraph 5.9.2. That means that the second explanation – an increased emphasis on cattle as supporters of arable farming – is more likely. LSI data show a second size increase in cattle in the Middle Roman period – the first size increase occurred in the Early Roman period –, which was much larger than the first one. In the two settlements for which size changes could be studied in detail (Tiel-Passewaaijse Hogeweg and Geldermalsen-Hondsgemet), the largest increase takes place around A.D. 150. A size increase would be desirable from the point of view of arable farming, with larger cattle being more suited to draw a plough, especially in heavier soils. This would fit in with the intensification of arable farming. However, larger cattle may also have been desirable with regard to meat production, with a larger amount of meat per animal. Larger animals would also have provided larger skins, which could be a third factor behind the size increase. The combination of the size increase with increased slaughter ages and a possible expansion of arable land (see below) make intensification of arable farming the most likely explanation. It is unclear how the size increase was brought about exactly, but this is likely to have been a combination of imported cattle – perhaps from a different source than those imported in the 1st century A.D.[774] – and interbreeding of larger cattle with the local type. Additionally, changed feeding regimes may have played a role, although this is likely to have been limited. Evidence for fodder has been found for several settlements, but it is not possible at the moment to say whether the type of fodder changed over time.[775]

Large granaries – at least in relation to the traditional granaries found in the region – are found in the 2nd century. Their capacity is much larger than the needs of the local population, and suggests that a surplus of cereals was produced at this time.[776] It has been suggested that the large granaries were used to store cereals collected from surrounding settlements,[777] but in that case this would also represent a surplus. In the late 1st or early 2nd century, large systems of ditches were constructed in the land surrounding rural settlements. There are several explanations for this, but the one that fits in with the other developments in farming is that of extending and draining land.[778] Some of this land may have been used for arable farming.[779]

[774] This would explain why the prevalence of certain non-metric traits does not change until the Middle Roman period. See paragraph 7.5.2.1.

[775] See paragraph 5.8.1.

[776] Groot *et al.* 2009. The largest granaries in Tiel-Passewaaijse Hogeweg and Wijk bij Duurstede-De Horden date to the second half of the 2nd century.

[777] Vos 2009, 256-257.

[778] Other explanations are measuring the land for assessing its agrarian potential, possibly within the context of Roman taxation, and an increased importance of marking ownership of land. The field system in Tiel-Passewaaijse Hogeweg is dated A.D. 90-120, while that in Wijk bij Duurstede-De Horden is dated A.D. 100-150. Heeren 2009, 238-239, 248-250; Vos 2009, 105, 115-116, 257-258.

[779] Groot/Kooistra 2009.

The most obvious trends have been discussed here, but in reality the rural settlements show a great degree of variety in animal husbandry. Even within a small region with a similar geology, animal husbandry was not necessarily the same everywhere. The observed variations in species proportions can be explained in various ways. If we accept that they reflect actual animal husbandry practices, then the most likely explanations are complementary sites (with a division of agricultural tasks) or relative specialisation in certain animals or animal products for the market. Differentiation in animal husbandry and relative specialisation is also seen within some settlements, where horse breeding could be linked to veterans and their families, while other households focused on keeping sheep. *Villa* sites and sites with a 'military flavour' show few distinguishing characteristics, but oysters, which are rare in rural settlements, were present in two *villae*, and a high proportion of cattle was found in two sites with a 'military flavour' and a high proportion of pig in one site.

Overall, developments in farming in the Middle Roman period are much more significant than those in the Early Roman period. The increase in production for the market (beef cattle, horses, pork, wool, cereals) goes hand in hand with a greater dependency on the market for goods that were previously produced in the rural settlements, such as pottery, textile and leather goods. From the early 2nd century, all pottery came from the market; other products acquired there include iron tools, mirrors, perfume bottles, clothes, jewelry and brooches. While some of these latter products can be seen as luxury goods, pottery and clothes fulfill basic needs.[780]

7.7.2.2 Food supply to army and town

The triplot for the Middle Roman period shows less diversity than that for the Early Roman period (fig. 7.28). This suggests that the supply of meat had become standardised by the end of the 1st century.[781] An exception is formed by the two assemblages from the *castra*, with less cattle and more pig and sheep. What is clear is that the meat supply relied heavily on cattle, even more so than in the previous period. The cattle were slaughtered in the consumer sites, and in the town of Nijmegen, the carcasses were processed by professionals, on a large scale, not just for meat, but probably also for their hides, horn and grease. LSI data suggest that the cattle could have been supplied locally. Slaughter ages reveal that there was a combination of prime-meat cattle and older animals, which would have been used for secondary products first. The latter category seems to have outnumbered the younger beef cattle. This highlights an apparent paradox: cattle were the most important animals in terms of meat quantities, but they show the least specialisation in terms of meat production. This becomes even clearer when their slaughter ages are compared with those of pigs and sheep: both these species are slaughtered at younger ages in consumer sites than in the rural settlements, which indicates that they were prime meat animals, and that exploitation in the countryside was aimed at meat production. The first role of cattle, on the other hand, was to provide secondary products: labour and manure. This ties in with the intensification of arable farming observed for this period. The importance of secondary products and the lack of specialised beef production is also known from other regions, and in fact this does not seem to have changed until the post-medieval period.[782] A difference in average withers height of sheep/goat from rural and consumer sites could be due to a supply of sheep/goats from outside the region, to different sex ratios – with more (larger) rams slaughtered in consumer sites – or to a different ratio of sheep and goats. With few sex determinations and positively identified bones of sheep and goat, it is not possible to establish which explanation is most likely.

Some cereals, such as bread and spelt wheat, were imported from further away, while others were supplied by local farmers. Exotics, such as fig, olive and grape, were imported from the Mediterra-

780 Heeren 2009, 185.

781 As was also the case for the supply of cereals. Personal communication Laura Kooistra.

782 Maltby 1994; O'Connor 2000a, 163; 2000b; Peters 1998, 237; Pigière/Lepot 2013; Thomas 2008; Wilson 1994.

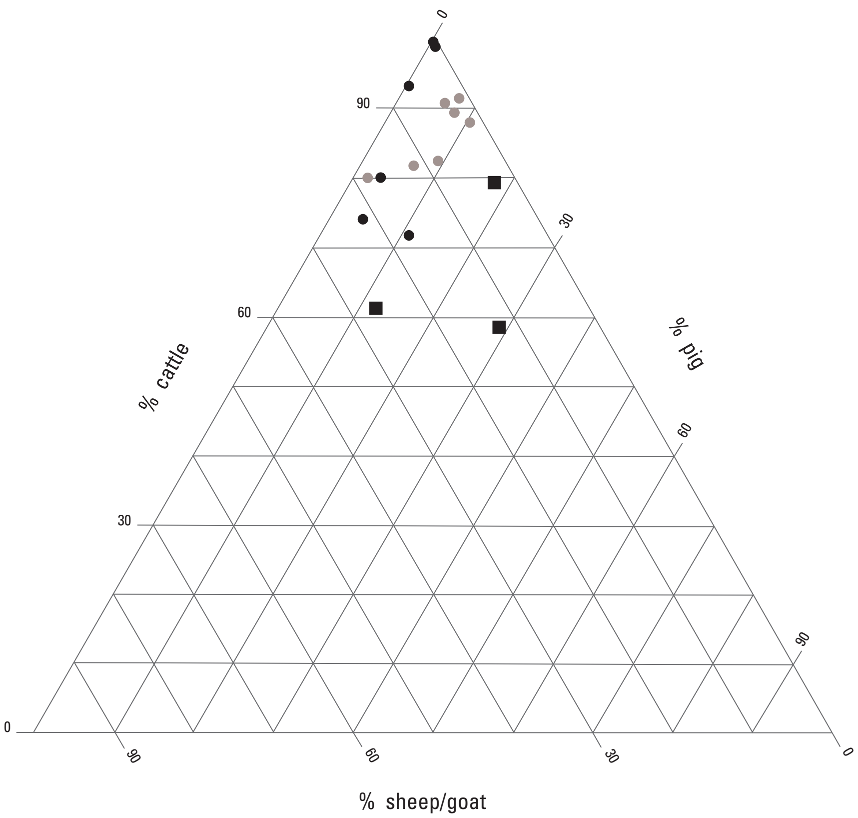

Fig. 7.28. Triplot showing the proportions for the main meat providers cattle, sheep and pig for Middle Roman consumer sites (with the exception of temples). Black circles: urban Nijmegen; grey circles: vici and canabae; squares: military sites.

nean. While it was mostly the town and army that were supplied with food by the rural settlements, some food travelled in the opposite direction. The increased importance of the market for rural people, not just to sell produce to but also to acquire goods, has already been mentioned in the previous paragraph. It was not just material goods that went from town to countryside, but also food, such as spelt and bread wheat, herbs, beet, damson and walnut (Roman introductions which were then cultivated in rural sites), oysters and perhaps also chickens (which, after their introduction, would have been bred in the rural settlements). *Amphora* sherds in rural sites could indicate wine and olive oil, which would then also have moved from town to countryside.

Van Driel-Murray sees a move from complete self-sufficiency of the army to more civilian involvement in the 2nd century.[783] Although she is writing about leather – specifically about shoes – a similar development may have taken place in the supply of other goods and food. In fact, after c. A.D. 150, the army and civilian populations had access to the same pottery.[784] This would explain why the strongest changes in farming are seen in the 2nd century: if the supply of food and goods to the army was now in civilian hands, then local farmers may have had better opportunities to sell their livestock and products – especially horses at this time –, and to add imported livestock to their herds, which further increased the size of rural cattle.

783 Van Driel-Murray 1985.

784 Van Kerckhove 2008, 69.

7.7.3.1 Agriculture

The main development in animal husbandry in the Late Roman period is an increase in pig and cattle and a decrease in sheep and horse (fig. 7.29). Sex ratios of both cattle and pigs change in this period, in the case of cattle from a dominance of cows to equal proportions, and in the case of pigs from roughly equal proportions to a dominance of males. Since the proportion of males increases for both species, this could be a sign of decreasing intensification of meat production, with fewer male cattle and pigs sold to the market as youngsters. The exploitation of cattle differs between settlements, but an emphasis on older animals is found more often than one on younger meat animals. The average withers heights of cattle and horse continue their increase in the Late Roman period. An increase in the hunting of wild animals has been related to the population decline and the regeneration of woodland. This does not explain the increase in pig, because regenerated woodland in the river area would not have contained many oak trees. Furthermore, environmental reasons are probably not the best explanation for species proportions in the River Area, since the landscape is even less suitable for sheep than for pigs.[785] As far as butchery is concerned, chop marks continue to increase in the region as a whole and in two individual settlements.

The Late Roman period is distinctive with regard to its animal husbandry, with significant changes in species proportions and sex ratios of the main livestock. This may have been related to the collapse of markets, population decline and smaller settlement density (and resulting environmental change). On the other hand, it is possible that a change in ethnicity would have caused changes in animal husbandry. A change in ethnicity has been observed in the material culture and building style of the Late Roman period.[786] Variability between rural settlements is seen in the LSI data for cattle: width measurements from Tiel-Passewaaijse Hogeweg are significantly larger than those from Tiel-Oude Tielseweg. Perhaps this can be explained by a difference in ethnicity of the inhabitants, with two different herds that did not interbreed.

It is not clear exactly where the Late Roman immigrants would have come from, other than 'north of the Rhine'. Zooarchaeological studies of settlements in the northeastern coastal zone of the Netherlands show that pig did not play an important role in animal husbandry.[787] Closer to the river Rhine, in the east of the Netherlands, pig was more important, although the proportion of pig in the River Area is higher in all Late Roman sites.[788] The lack of zooarchaeological data from the areas close to the Rhine and outside the Roman Empire means that it is not possible at the moment to compare animal husbandry on different sides of the border.

7.7.3.2 Food supply to army and town

With only one consumer site in the Late Roman period – a *castellum* in Nijmegen – and a relatively low number of rural sites, studying food supply is not easy. The species proportions for the Late Roman

[785] Despite the unsuitability of the landscape, sheep or goats were common, especially in the Early Roman period.

[786] E.g. Heeren 2006, 90; 2009, 72-73; Van Renswoude 2009b, 472.

[787] E.g. Paddepoel: 0.9 % pig (200 B.C. – A.D. 250; Knol 1983); Englum: 0.3 % (A.D. 0-150) and 1.7 % pig (A.D. 100-250; Prummel 2008). However, in settlements just across the modern border with Germany, pig has much higher proportions of 6, 11.8 and 14.3 % (Bentumersiel and Jemgumkloster, both dated 1st century B.C. – 3rd century A.D.; Küchelmann 2013; Zawatka/Reichstein 1977).

[788] Heeten: 16 % pig (4th century; Lauwerier *et al.* 1999). The low percentage of pig for Wijster could be due to the bad preservation in this site, and can therefore not be taken as representative (Clason 1967).

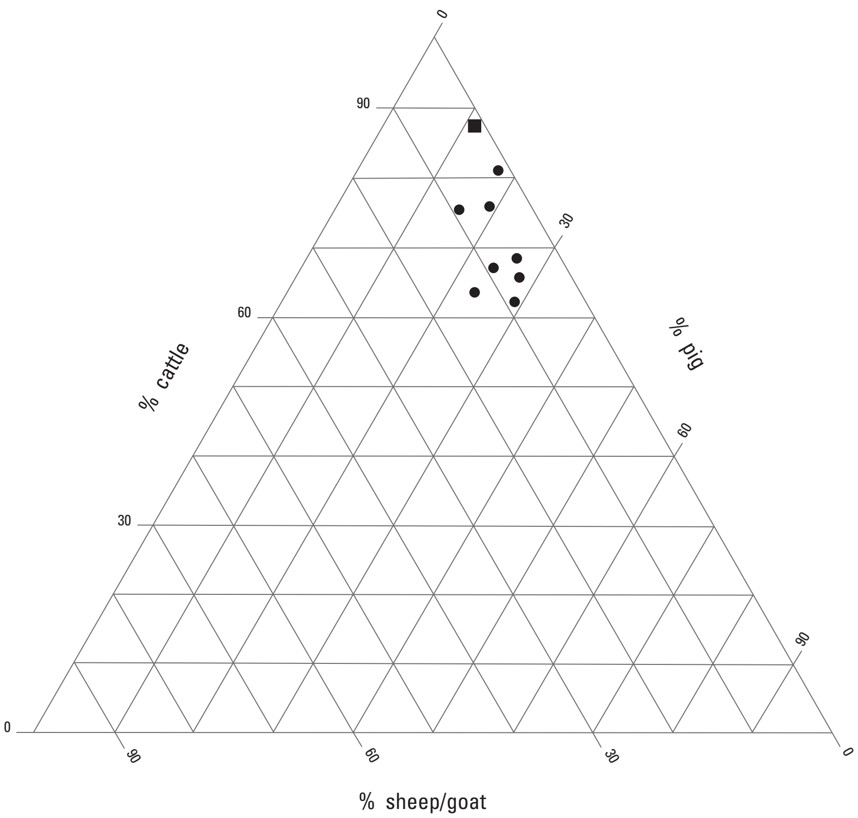

Fig. 7.29. Triplot showing the proportions for the main meat providers cattle, sheep and pig for Late Roman sites. Circle: rural settlement; square: Nijmegen-Valkhof.

castellum differ from those in the rural settlements, with a high proportion of horse (only one rural site has a similar proportion) and a much lower proportion of pig than is found in the rural sites (figs. 5.11 and 6.1). Most of the cattle are slaughtered as adults, with a smaller slaughter peak in the fourth year. The high number of adult cattle is similar to that found in two of the rural settlements, but in rural sites more animals are killed in the first three years. LSI data indicate that the cattle in Nijmegen were not supplied by the Late Roman rural settlements included in this study, but that they form a distinct, larger population. It is possible that Nijmegen was supplied by a small surrounding region, which does not include the rural sites included here, all of which are located further than 15 km away. With a smaller population in Nijmegen in this period, perhaps food supply could have been arranged at a more local level than in the previous period. Unfortunately, there are no zooarchaeological data from Late Roman rural settlements close to Nijmegen. A second explanation is that the *castellum* was supplied from a different region. If existing regional trade networks had collapsed, then it may have been necessary to supply food from further away. The question remains whether it would have been safe to transport cattle over longer distances in periods of instability. Whatever the explanation is, the Late Roman forts were isolated posts,[789] and it should therefore not be surprising that there is a difference between the livestock found in the *castellum* and in the countryside.

[789] Willems/Van Enckevort 2009, 27.

8. Final thoughts

8.1 FOOD SUPPLY

In the last decades B.C., the Roman army became a permanent presence in the Netherlands. Initially, food supply relied strongly on pigs,[790] which were either bred by the army locally or arrived through military supply lines. Cattle seem to have been requisitioned locally, although some may also have come from further away. Since the local farmers were not yet used to producing surplus food, it was not possible for the army to rely on local supply completely. A similar food supply strategy is seen in other early military sites, such as Dangstetten and Velsen, where pig is also the most common species.[791] In contrast to this, in the early fort of Alchester (UK), the species spectrum, slaughter ages and size of livestock suggest local procurement.[792] This first stage did not last long. Cattle soon became increasingly important for military meat consumption, and there is now evidence for the import of cattle as well as the provisioning with local livestock. Consumers` dietary preference can be seen in the slightly higher proportion of pigs in military sites.

From the early 1st century A.D., Nijmegen developed as an urban as well as a military centre. This resulted in another group of consumers that needed to be fed. Cattle provided most of the meat consumed in the town. In the Early Roman period, pig is the second species. Perhaps these pigs were raised in the town, as has been suggested for other regions.[793] In the early Middle Roman period, sheep or goat is the second species, which can either be explained by availability or dietary preference of urban people.

The increasing numbers of imported pottery and other material culture found in rural settlements, especially from the late 1st century onwards, suggests that the supply of livestock to the army and town was not a one-way process, and that the farmers benefited. The town of Nijmegen must have been an important market place for the surrounding region. Inhabitants from rural settlements in the Dutch River Area brought their surplus produce and animals here. The animals were transported on the hoof and slaughtered in the town. Army representatives could have bought cattle here, or have travelled to the rural settlements.

For both army and town, the zooarchaeological data suggest direct distribution rather than indirect distribution.[794] Species proportions are similar to those in the rural settlements, both young and older animals are found, and all body parts are present. Direct distribution implies that farmers were in control and herd security determined which animals are supplied. Furthermore, the distance between producer and consumer was small. This suggests small-scale transactions between individual producers and consumers rather than merchants mediating between farmer and consumer and operating on a large scale. While not enough is known about butchery in the consumer sites, there is evidence for large-scale processing of cattle in Middle Roman urban Nijmegen which is similar to that found in other Roman towns. This fits better with indirect distribution. This means that while supply of live-

790 Thijssen 1988; Cavallo *et al.* 2008.

791 Uerpmann 1977; Cavallo *et al.* 2008.

792 Thomas 2008. The difference can perhaps be explained by the difference in date, with Alchester about half a century later than the other sites.

793 Cool 2006, 84; Hesse 2011, 219, 233; Lepetz 1996, 89.

794 See paragraph 1.3.2.

stock to the consumer sites was not under the control of the consumer, the processing of cattle was standardised to some degree.

Food supply for the non-agrarian population in the research area need not all have been produced within the border of the Roman Empire. There are indications that especially cattle were also supplied from north of the Rhine. One example is the settlement of Feddersen Wierde, where Roman imports were found, as well as donkeys and mules.[795] An increase in the number of cattle stalls suggests an increase in the scale of cattle breeding, and this is the likeliest trade product of this region.[796] The comment from Tacitus on the Frisian revolt being a reaction against unrealistic tax demands of cattle hides is another indication that cattle or cattle products travelled across the border in the early 1st century.[797] Stallibrass emphasises the importance of cattle droving, which could occur over long distances.[798]

In Roman Britain, movement of cattle has been investigated by isotopic analysis.[799] This field of research holds a lot of potential, just as analysis of ancient DNA,[800] but so far research in the Roman Netherlands has not made use of this potential.

8.2 Changes in farming

While the presence of the army and town meant an increase in the number of people in the region, the rural population of the Dutch River Area also increased, especially in the 2nd and 3rd centuries. This is clear from the increase in simultaneous farmhouses in several larger settlements, such as Tiel-Passewaaij and Wijk bij Duurstede-De Horden, but even more so from the distribution of known find spots for the region.[801]

So how did farmers respond to the increased demand for food? First, they specialised to a limited extent in certain products, such as wool and horses. This relative specialisation could differ between settlements and even between households within a settlement. Batavians were known for their cavalry units, and clearly had an affinity with horses. Furthermore, the connections that veterans had with the army seem to have made it easier for them to specialise in breeding and supplying horses (fig. 8.1). The study of individual households, which revealed this link between horse breeding and veterans, provides one of the best chances of discovering agency in farming. The spread of Roman butchery methods and accompanying tools is another example where agency can be observed. Another example of specialisation is the evidence for wool production found in 1st-century Tiel-Passewaaijse Hogeweg. The decline of this wool production around 100 A.D. coincided with the 10th legion leaving Nijmegen, which led to a tentative hypothesis that the wool was produced specifically for the 10th legion.[802] A parallel development was observed in the Swiss *villa* of Biberist, where evidence for wool production was found for the 1st century, when a legion was stationed at *Vindonissa*, but not for later periods, when the legion had left.[803] Although relative specialisation can be identified, farming was mostly non-specialised, with mixed farming and exploitation of several animal species for a range of products being normal.

Second, the size of cattle and horses increased. This can reflect catering to the customer`s demand for larger animals – for whatever reason –, intensification of animal husbandry – more meat per animal, or intensification/extensification of arable farming – larger plough oxen could draw heavier

795 Johnstone 2008, 142. Due to the problems involved with differentiating between horses, donkeys and mules, there are no positive identifications for sites in the research area.

796 Wells 1996.

797 *Annals* 4, 72.

798 Stallibrass 2009.

799 Minniti *et al.* 2014.

800 Colominas *et al.* 2014.

801 Vossen/Groot 2009, 88, 90, fig. 3.

802 Groot 2008, 72.

803 Deschler-Erb 2006; Deschler-Erb/Akeret 2011, 30.

8.1. Veterans had connections with the army, which may have put them in a better position to specialise in breeding horses.

ploughs or in heavier soils. The increase in size is likely to have been due to the introduction of larger cattle and horses, which were then crossed with the local animals. An increase in the size of livestock is seen throughout the northwestern provinces.[804]

Third, there is evidence for both intensification and extensification of arable farming. The first can be concluded from the increase in slaughter ages of cattle – indicating that products of the living animals, such as manure and traction, were becoming more important –, while the second is seen in the expansion of arable land, which has been suggested for Tiel-Passewaaij.[805] Intensification of arable farming is found in other regions as well. Peters saw the increased importance of cattle and higher slaughter ages as evidence for intensification as well as for the increased importance of cattle as transport animals.[806] The Thames Valley (UK) also saw an increase in the proportion of cattle in combination with a shift to exploitation of secondary products.[807] At the same time, there was a change in sex ratios of cattle from mostly females to mostly males. In Northern France, exploitation of cattle varies between sites, but some rural sites or *villae* show high proportions of older cattle and a dominance of males, which suggests that traction was most important. The increase in cattle at the expense of sheep during the Roman period supports this.[808] In the Dutch River Area, cows seem to dominate

[804] Albarella *et al.* 2008; Dobney *et al.* 1996, 31-33; Johnstone 2004; Lepetz 1996; Peters 1998; Schibler/Schlumbaum 2007; Schlumbaum *et al.* 2003; Teichert 1984.

[805] Groot/Kooistra 2009.

[806] Peters 1998, 237.

[807] Hesse 2011.

[808] Lepetz 1996, 83, 86, 94.

the rural assemblages. Mortality profiles show little or no evidence for dairying.[809] The occurrence of pathological lesions associated with traction on cow bones suggests that cows as well as oxen were used for traction.[810] The development of *villae* in many regions is itself evidence for intensification and extensification of arable farming, and also for specialisation, since there was a strong focus on cereals in most *villae*. However, true *villae* are not found in our research area.

While certain trends in farming can be recognised in the River Area and other regions, there is a large degree of variability in species proportions and exploitation. Such variability was also observed for the Thames Valley and Northern France.[811] Hesse believes that economic concerns – market demand – are the main factor determining the nature of animal husbandry, followed by environmental factors and cultural tastes. We can add agency to this, since a farmer's life history, experience, knowledge and personal connections would also have been important.

8.3 SCALE OF PRODUCTION

Agrarian production was small in scale, but this was compensated for by the large number of rural settlements. We have already seen in paragraph 7.1.4 how small-scale horse breeding could have supplied all the horses needed by the army. The question is whether this also applied to other agrarian products. Groot *et al.* compare production and storage capacity with local requirements for food for two rural settlements and conclude that – if only cattle were stabled, and stables were full –, then a surplus of 7-40 cattle could have been produced per year.[812] Production of a surplus of cereals (emmer wheat and barley) was possible for all periods, although it was small in some. Another publication, focusing on barley as fodder, concluded that a substantial amount of the barley required by the army could have been produced locally.[813] While the figure used for the daily amount of barley needed by a horse was very high, the number of horses was underestimated, and draft animals and horses in the town were not taken into account. Much of the cereals consumed by urban and military people came from outside the research area, since it is unlikely that spelt and bread wheat were grown here.

While the army had a strong presence in the research area, the urban part of the population was relatively small compared to other regions, with only one urban centre and few or no large *vici*. Even the size of the army was limited after the legion that was stationed in Nijmegen in the Flavian period left. The population for late 1st-century Nijmegen has been estimated at 10,000 (military and civilian), while the rural population consisted of over 50,000 people in the Middle Roman period.

Using the figures from Groot *et al.* 2009, and assuming that all meat came from cattle to simplify matters, 2735 animals would have been needed per year to feed the military and urban population of Nijmegen.[814] Lepetz used a different approach to calculate the number of animals needed to feed the population of Roman Arras. He assumed a meat consumption per person of 50-200 g per day, and a meat yield of 320 kg per cattle.[815] This is based on a withers height of 135 cm, which is much larger than the average of 117 cm found for Middle Roman consumer sites in the research area. If we take a meat yield of 200 kg,[816] 913 to 3650 cattle would be needed per year in Nijmegen. Considering the high number of settlements (c. 1000) and the potential of 7-40 surplus animals per settlement, local

809 Cow's milk was of little importance in Roman Italy, and this may also have been the case in the Roman provinces. MacKinnon 2004, 94; White 1970, 206.

810 Groot 2005c.

811 Hesse 2011; Lepetz 1996.

812 Groot *et al.* 2009.

813 Vossen/Groot 2009.

814 Based on 10 % meat in the diet.

815 Lepetz 1996, 137-138.

816 Roughly in the middle between Lepetz's figure and the meat yield used by IJzereef for small Bronze Age cattle (live weight 200 kg, meat yield is 30 % of live weight). IJzereef 1981, 184.

supply of meat would not have been a problem. Of course, in reality sheep and pigs also contributed to the consumer diet, we have not considered the consumer sites outside Nijmegen, and the proportion of meat may have been much higher than assumed. Nevertheless, we can conclude that many small-scale operations resulted in large-scale production of livestock when seen on a regional level.

8.4 What did the Romans do for us? Exploitation versus opportunity

The Roman conquest of Northwestern Europe had a major impact on local agricultural economies, who were now faced with a demand for food and other agrarian products and adapted their farming to accommodate this demand.[817] What were basically self-sufficient agricultural societies in the Late Iron Age were transformed into market-oriented agricultural economies in the Roman period. This was accomplished in different ways. First, arable farming seems to have become more important, and there are signs of extensification and intensification, especially from the late 1st century onwards. Second, output of livestock, whether as meat or traction, was increased by introducing and breeding larger animals. Third, relative specialisation in certain products occurred. Horse breeding forms the main type of specialisation, and provided an important surplus product especially in the 2nd and 3rd centuries. Despite these developments, it is striking how little farming changed in other respects. Mixed farming continued to be practised, with a range of crops and animals. This is probably due to the scale of production, which was small, and the environmental constraints of the River Area, which did not allow the large-scale growing of cereals that is found in the *villa* landscapes to the south.

Farmers were self-sufficient with regard to most of their food, but selling some of their produce on the market allowed them to become dependent on others for goods such as pottery and textiles. While exploitation of rural people is likely to have occurred, especially in the earliest period, opportunity seems to have been more important.

8.5 From self-sufficiency to market production

So, based on this case study, what can we say about the way in which previously self-sufficient rural communities responded to a market demand for agrarian products? How did they achieve a move from subsistence farming to market production? What strategies did they employ to increase their production? The rural communities in the Roman Dutch River Area responded at first by increasing the emphasis on meat production of cattle, by slaughtering them younger and by increasing their size. Any surplus cattle were supplied to the army and town. Specialisation in some products, such as wool and horses, is visible, but was always secondary to maintaining the mixed farming system. Close to the town of Nijmegen, more pigs were kept, which can be linked to the proximity of the market. The most significant changes are seen around the mid-2nd century A.D., a century and a half after the Roman army first arrived in the region. Horse breeding becomes much more important, and there are clear indications that arable farming was intensified, leading to an increase in production. The large granaries that are found in the rural settlements also reflect the larger scale of production. The output per animal was larger, as the size of cattle increased even further. Pork production intensified but this was only at a small scale. An increase in cattle size and an increase in the importance of arable farming

[817] Peace and the resulting prosperity that lasted for about two centuries after the Roman conquest of course also affected agriculture.

is also seen in other regions of the northwestern Roman Empire. The main difference between our and other regions seems to be the scale of production. The Dutch River Area is characterised by a lack of villas, the prototypical Roman agrarian businesses aimed to produce food for the towns. Instead, we find small settlements, which may only have produced a small surplus each. However, the settlement density is so high that the total amount of food produced would have been substantial.

It was not just farming that changed in response to market demand; the impact also involved a dependency on the market. The focus on producing marketable agrarian products went hand in hand with a loss of self-sufficiency in crafts such as production of pottery, textiles and leather. Whereas these goods had previously been made in the rural settlements, farmers now bought the finished products at the market, even if they still produced the raw material (such as wool) in some cases. Despite this growing dependency on the market, it is likely that farmers continued to be self-sufficient with regard to most of their food.

We have also gained insight into the strategies that were used in the provisioning of the Roman army and town in the research area. Only in the earliest phase of the military occupation do we find self-sufficiency (raising their own pigs) and the only hint of forceful requisitioning (young cattle). The similarity of species proportions and slaughter ages for the earliest fort in Nijmegen to those in other regions suggests that the Roman army had a common strategy when it came to food supply in newly occupied regions. It was not long before a mix of local supply and imported meat is seen, followed in the late 1st century by a predominantly local supply (at least for meat). By this time, the meat supply had become standardised, and reflects an adaptation to local availability, with cattle dominating the diet in the countryside, the town and the military camps. Cereals continued to be imported, because a local supply of spelt and bread wheat was not achievable in this region. In the Late Roman period, the connection between Nijmegen and the wider surrounding region is lost. At the moment it is not clear where the meat consumed in Late Roman Nijmegen was coming from, but it certainly did not come from the rural settlements included in this study.

So, meat was supplied from local sources during much of the Roman period. But what was the interaction between farmers and urban and military consumers like? Should we see the Roman authorities as demanding certain products from the farmers? Or did the farmers decide what to produce and what they could spare? There are some indications that the latter applied to our region, and that demand did not drive production to any great extent. First, the proportions of the animals found in the town and army camps are similar to those found in the rural settlements, and do not differ very much from those found in the preceding Late Iron Age. If consumers had dietary preferences different from those of the farmers, they were only able to satisfy those to a limited degree. Second, the slaughter ages of cattle found in the town and army camps show a mixture of young and old animals. If production was aimed entirely at producing meat, then we would expect to see mostly young animals. The same arguments suggest that the contact between the farmers and the buyers of the meat was direct, and that merchants or middlemen did not play a role. The variety in species proportions and exploitation of livestock in rural settlements further suggests that farmers decided for themselves how to farm, and were not given directions from above.

The Roman Empire consisted of a multitude of regions, each with its own history, culture and environment. After the Roman army arrived in the provinces, each region had to find its own solution to deal with the Roman occupation and the challenges this provided for animal husbandry and food supply. For the Dutch River Area, the solution consisted of a continuity of farming practices in combination with an increase in the scale of production. With a high settlement density, each individual settlement only needed to supply a relatively small surplus to feed the town and army. Local farmers determined production, and supplied those products that were traditionally important in their agrarian regime: cattle, barley and emmer wheat. They also took advantage of the new opportunities provided by the market, and specialised to some extent in products such as horses and wool. The Roman consumers had to adapt to the availability of food in the region, and when this was not acceptable to them, they had to import food. Spelt and bread wheat were imported from other regions, but there is little evidence that meat was imported at a large scale. This system arose during the 1st century A.D. and worked until the later 3rd century. It was only during the chaos of the later 3rd century that the system collapsed, and food production and food supply changed.

Bibliography

Abbreviations

AAS Amsterdam Archaeological Studies
ADC Archeologisch Diensten Centrum, Amersfoort
BAPA Beiträge zur Archäozoologie und Prähistorischen Anthropologie
BAR Brit. Ser. British Archaeological Reports, British Series
BAR Int. Ser. British Archaeological Reports, International Series
BRA Basisrapportage Archeologie
BROB Berichten van de Rijksdienst voor het Oudheidkundig Bodemonderzoek
FiA Forschungen in Augst
IJO International Journal of Osteoarchaeology
JALC Journal of Archaeology in the Low Countries
JAS Journal of Archaeological Science
JRA Journal of Roman Archaeology
JROB Jaarverslag ROB
NAR Nederlandse Archeologische Rapporten
NO Nederlandse Oudheden
RAM Rapportages Archeologische Monumentenzorg
ROB Rijksdienst voor het Oudheidkundig Bodemonderzoek, Amersfoort
ZAN Zuidnederlandse Archeologische Notities
ZAR Zuidnederlandse Archeologische Rapporten

Classical sources

Tacitus, *Annales*, ed. J. Jackson, 1979-1986 (3 vols), London/Cambridge Mass. (Loeb Classical Library).

Tacitus, *Germania*, ed. M. Hutton, rev. E.H. Warmington, 1980, London/Cambridge Mass. (Loeb Classical Library).

Tacitus, *Historiae*, ed. C.H. Moore, 1979-1980 (2 vols), London/Cambridge Mass. (Loeb Classical Library).

Varro, *De re rustica*, ed. W.D. Hooper, 1935, London (Loeb Classical Library).

Apicius, *De Re Coquinaria,* ed. B. Flower, E. Rosenbaum, 1958, London.

Petronius, *Satyricon,* ed. A.D. Leeman, 1989, Amsterdam.

Modern sources

Aarts, J., 2014: A frog's eye view of the Roman market: the Batavian case, in Van der Spek, R.J./J.L. van Zanden/B. van Leeuwen (eds), *A History of Market Performance. From Ancient Babylonia to the modern world*, London, 394-409.

Albarella, U., 1997: Shape variation of cattle metapodials: age, sex or breed? Some examples from mediaeval and postmediaeval sites, *Anthropozoologica* 25-26, 37-47.

Albarella, U., 2002: 'Size matters': how and why biometry is still important in zooarchaeology, in K. Dobney/T. O'Connor (eds), *Bones and the man. Studies in honour of Don Brothwell*, Oxford, 51-62.

Albarella, U./C. Johnstone/K. Vickers, 2008: The development of animal husbandry from the Late Iron Age to the end of the Roman period: a case study from South-East Britain, *JAS* 35, 1828-1848.

Alföldy, G., 1968: *Die Hilfstruppen der römischen Provinz Germania Inferior*, Düsseldorf.
Amorosi, T., 1989: *A postcranial guide to domestic neo-natal and juvenile mammals. The identification and aging of Old World species*, Oxford (BAR Int. Ser. 533).
Bakels, C.C., 1996: The pollendiagram Voerendaal-7, in L.I. Kooistra, *Borderland Farming. Possibilities and Limitations of Farming in the Roman Period and Early Middle Ages between the Rhine and Meuse*, Assen, 139-146.
Bakels, C.C., 2009: *The Western European Loess Belt. Agrarian History, 5300 BC–AD 1000*, Dordrecht.
Bakels, C./S. Jacomet, 2003: Access to luxury foods in Central Europe during the Roman period: the archaeobotanical evidence, *World Archaeology* 34 (3), 542-557.
Bechert, T./W.J.H. Willems, 1995: *De Romeinse rijksgrens tussen Moezel en Noordzeekust*, Utrecht.
Bekkema, M./M. Groot/M. van Haasteren/K. Scharringhausen, 2011: *Dierlijk bot uit Wijk bij Duurstede-De Geer: midden-Romeinse tot en met Karolingische tijd*, Amsterdam (ZAN 262).
Belayche, N, 2008: Religion et consommation de la viande dans le monde romain: des réalités voilées, in W. Van Andringa (ed.), *Sacrifices, marché de la viande et pratiques alimentaires dans les cités du monde romain*, Turnhout (Food and History 5 (1)), 29-43.
Bendrey, R./T.E. Hayes/M.R. Palmer, 2009: Patterns of Iron Age horse supply: an analysis of strontium isotope ratios in teeth, *Archaeometry* 51, 140-150.
Berger, T.E./J. Peters/G. Grupe, 2010: Life history of a mule (c. 160 AD) from the Roman fort Biriciana/Weißenburg (Upper Bavaria) as revealed by serial stable isotope analysis of dental tissues, *International Journal of Osteoarchaeology* 20 (2), 158-171.
Berendsen, H.J.A./E. Stouthamer, 2001: *Palaeogeographic development of the Rhine-Meuse delta, the Netherlands*, Assen.
Berke, H., 1989: Funde aus einer römischen Leimsiederei in Köln, *Kölner Jahrbuch für Vor- und Frühgeschichte* 22, 879-892.
Blom, E./G.L. Williams, 2008: *Archeologisch onderzoek op de locaties Tiel Medel Krommewei en Ooijsche Wetering. Twee archeologische opgravingen*, Amersfoort (ADC-rapport 1010).
Blom, E./W. Roessingh, 2009: Synthese, in W. Roessingh/E. Blom, 2009: *Een omgreppeld nederzettingsterrein uit de Romeinse tijd*, Amersfoort (ADC-rapport 1426), 113-126.
Blom, E./W. Roessingh, 2010a: *Heteren Uilenburg: 1500 jaar bewoning op een crevasse*, Amersfoort (ADC-rapport 1664).
Blom, E./W. Roessingh, 2010b: Synthese, in E. Blom/W. Roessingh, *Heteren Uilenburg: 1500 jaar bewoning op een crevasse*, Amersfoort (ADC-rapport 1664), 139-159.
Blom, E./L.M.B. van der Feijst/H.A.P. Veldman, 2012: *Plangebied Keizershoeve I. Archeologisch onderzoek op 'De Grote Aalst' te Ewijk*, Amersfoort (ADC-rapport 2000).
Blom, E./H.A.P. Veldman, 2012: Inleiding, in E. Blom/L.M.B. van der Feijst/H.A.P. Veldman (eds), 2012: *Plangebied Keizershoeve I. Archeologisch onderzoek op 'De Grote Aalst' te Ewijk*, Amersfoort (ADC-rapport 2000), 13-20.
Bloo, S.B.C./C.G. Wiepking, 2002: Aardewerk, in E.E.B. Bulten (ed.), *IJsselstein, Lage Dijk N210*, Amersfoort (ADC-rapport 133), 40-54.
Boessneck, J., 1969 (2nd ed.): Osteological differences between sheep (*Ovis aries* Linné) and goat (*Capra hircus* Linné), in D. Brothwell/E. Higgs (eds), *Science in archaeology*, London, 331-358.
Bogaers, J.E., 1955: *De Gallo-Romeinse tempels te Elst in de Over-Betuwe*, 's-Gravenhage (NO 1).
Bogaers, J.E./J.K. Haalebos, 1988: Opgravingen op het terrein van het voormalige Canisiuscollege, 1987, *Numaga* 35 (2), 25-41.
Bogaers, J.E./J.K. Haalebos, 1989a: Opgravingen op het terrein van het voormalige Canisiuscollege, 1988, *Numaga* 36 (3-4), 49-60.
Bogaers, J.E./J.K. Haalebos, 1989b: Opgravingen op het terrein van het voormalige Canisiuscollege, 1989, *Numaga* 37 (4), 73-84.

Bogaers, J.E./J.K. Haalebos, 1992: Opgravingen op het terrein van het voormalige Canisiuscollege, 1990, *Numaga* 39, 7-23.

Bogaers, J.E./C.B. Rüger, 1974: *Der niedergermanischen Limes, Materialen zu seiner Geschichte*, Cologne (Kunst und Altertum am Rhein 50).

Bond, J.M./T.P. O'Connor, 1999: *Bones from medieval deposits at 16-22 Coppergate and other sites in York*, York (The Archaeology of York 15/5).

Boreel, G., 2007: Slakken en verbrande klei, in E. Verhelst/M. Schurmans (eds), *Oudheden uit Odijk. Bewoningssporen uit de Late IJzertijd, Romeinse tijd en Merovingische tijd aan de Singel West/Schoudermantel*, Amsterdam (ZAR 30), 132-140.

Bos, J.A.A./M.T.I.J. Bouman/C. Moolhuizen, 2009: Archeobotanisch onderzoek, in W. Roessingh/E. Blom (eds), *Een omgreppeld nederzettingsterrein uit de Romeinse tijd*, Amersfoort (ADC-rapport 1426), 97-100.

Brain, C.K., 1981: *The hunters or the hunted? An introduction to African cave taphonomy*, Chicago.

Brijker, J.M./J.A.A. Bos/F. Verbruggen, 2012: Het landschap, in E. Blom/L.M.B. van der Feijst/H.A.P. Veldman (eds), 2012: *Plangebied Keizershoeve I. Archeologisch onderzoek op 'De Grote Aalst' te Ewijk*, Amersfoort (ADC-rapport 2000), 25-68.

Brinkhuizen, D.C., 1989: Een wervel van een zeldzame vissoort uit de Romeinse haven van Velsen I (N.-H.), *Paleoaktueel* 1, 69-72.

Buitenhuis, H., 2002: Archeozoölogie, in J.S. Krist/J.B. de Voogd/J. Schoneveld (eds), *Een vindplaats uit de Late IJzertijd en Vroeg-Romeinse tijd aan de Schalkwijkseweg te Houten, terrein 14, Provincie Utrecht*, Groningen (ARC-publicatie 48), 135-168.

Buitenhuis, H., 2003: Faunaresten, in J.S. Krist (ed.), *Een Aanvullend Archeologisch Onderzoek op vindplaats 10 binnen het plangebied 'Deest aan het Water' te Deest, gemeente Druten (Gld.)*, Groningen (ARC-publicatie 76), 31-37.

Buitenhuis, H., 2005: Faunaresten, in S.J. Tuinstra/M.A. Huisman/A. Nieuwhof (eds), *Een archeologische opgraving in het kader van de aanleg van de infrastructuur in de VINEX-wijk Schuytgraaf te Arnhem-Zuid, gemeente Arnhem (Gld.)*, Groningen (ARC-publicatie 129), 55-60.

Bull, G./S. Payne, 1982: Tooth eruption and epiphysial fusion in pigs and wild boar, in B. Wilson/C. Grigson/S. Payne (eds), *Ageing and Sexing Animal Bones from Archaeological Sites,* Oxford (BAR Brit. Ser. 109), 55-71.

Bulten, E.E.B., 2002: *IJsselstein, Lage Dijk N210*, Amersfoort (ADC-rapport 133).

Bunnik, F.P.M., 1999: *Vegetationsgeschichte der Lössbörden zwischen Rhein und Maas von der Bronzezeit bis in die frühe Neuzeit*, Utrecht (PhD thesis University of Utrecht).

Carpaneto, G.M./M. Cristaldi, 1994: Dormice and man: a review of past and present relations, *Hystrix* 6 (1-2), 303-330.

Carrington, P., 2008: Feeding the wolf in Cheshire: models and (a few) facts, in S. Stallibrass/R. Thomas (eds), *Feeding the Roman Army. The Archaeology of Production and Supply in NW Europe,* Oxford, 18-30.

Cavallo, C./L.I. Kooistra/M. Dütting, 2008: Food supply to the Roman army in the Rhine delta in the first century A.D., in S. Stallibrass/R. Thomas (eds), *Feeding the Roman Army. The Archaeology of Production and Supply in NW Europe,* Oxford, 69-82.

Chaplin, R.E., 1971: *The study of animal bones from archaeological sites*, London.

Clason, A.T., 1967: The animal bones, in W.A. van Es, *Wijster, a native village beyond the imperial frontier 150-425 AD*, Groningen, 574-579.

Colominas, L./A. Schlumbaum/M. Saña, 2014: The impact of the Roman Empire on animal husbandry practices: study of the changes in cattle morphology in the north-east of the Iberian Peninsula through osteometric and ancient DNA analyses, *Archaeological and Anthropological Sciences* 6, 1-16.

Cool, H., 2006: *Eating and drinking in Roman Britain*, Cambridge.

Coy, J./J. Bradfield, 2010: Faunal remains from Roman deposits, in M. Maltby, *Feeding a Roman town. Environmental evidence from excavations in Winchester, 1972-1985*, Winchester, 307-317.

Creighton, J., 2006: *Britannia: the creation of a Roman province*, Abingdon.

Dark, P., 1999: Pollen evidence for the environment of Roman Britain, *Britannia* 30, 247-272.

Davies, R.W., 1969: The supply of animals to the Roman army and the remount system, *Latomus* 28, 429-459.

Davis, S.J.M., 2008: Zooarchaeological evidence for Moslem and Christian improvements of sheep and cattle in Portugal, *JAS* 35, 991-1010.

De Groot, R.W., 2013: *Een kijkje in het rijksmonument Merm-Wolfhoeksestraat te Elst. Aardgastransportleidingtracé Angerlo-Beuningen (A-663), catalogusnummer 10. Gemeente Overbetuwe. Archaeologisch onderzoek: opgraving*, Weesp (RAAP-rapport 2347)

De Hingh, A., 1992: *Botanisch onderzoek naar de voedseleconomie van de Romeinse vicus van Kesteren*, Leiden (Student's dissertation University of Leiden).

De Hingh, A., 2000: *Food production and food procurement in the Bronze Age and Early Iron Age (2000-500 BC) The organisation of a diversified and intensified agrarian system in the Meuse-Demer-Scheldt region (The Netherlands and Belgium) and the region of the river Moselle (Luxemburg and France)*, Leiden (Archaeological Studies Leiden University 7).

De Hingh, A.E./L.I. Kooistra, 1994: Voedselresten, in J.K. Haalebos/A.E. de Hingh/L.I. Kooistra, Opgravingen op het terrein van het voormalige Canisiuscollege 1993, *Numaga* 41, 29-33.

De Jong, T., 2005: Dieren bij het Heerlijk Huis, in H. Koopmanschap (ed.), *In Dongen stond een huis. De heerlijkheid Dongen in de Middeleeuwen*, Tilburg, 173-194.

Den Hartog, C.M.W., 2009: *Sportpark Terweide 2. LR41-42: Archeologisch onderzoek Sportpark Terweide*, Utrecht (BRA 18).

Derks, T., 2005: Romeinse religie en de heiligdommen van Elst, in H. van Enckevort/J. Thijssen (ed.), *In de schaduw van het Noorderlicht. Een Gallo-Romeinse tempel te Elst-Westeraam*, Abcoude, 20-31.

Derks, T., 2008: Samenvatting en conclusies, in T. Derks/J. Van Kerckhove/P. Hoff (eds), 2008: *Nieuw archeologisch onderzoek rond de Grote Kerk van Elst, gemeente Overbetuwe (2002-2003)*, Amsterdam (ZAR 31), 135-148.

Derks, T./N. Roymans, 2002: Seal-boxes and the spread of Latin literacy in the Rhine delta, in A.E. Cooley (ed.), *Becoming Roman, writing Latin? Literacy and epigraphy in the Roman West*, Portsmouth, Rhode Island (JRA Supplementary Series 48), 87-134.

Derks, T./N. Roymans, 2006: Returning auxiliary veterans: some methodological considerations, *JRA* 19, 121-136.

Derks, T./J. Van Kerckhove/P. Hoff, 2008: *Nieuw archeologisch onderzoek rond de Grote Kerk van Elst, gemeente Overbetuwe (2002-2003)*, Amsterdam (ZAR 31).

Derks, T./P. Hoff, 2008: Kaders, in T. Derks/J. Van Kerckhove/P. Hoff (eds), *Nieuw archeologisch onderzoek rond de Grote Kerk van Elst, gemeente Overbetuwe (2002-2003)*, Amsterdam (ZAR 31), 3-24.

De Roller, G.J., 2003: Botanische macroresten en hout, in J.S. Krist (ed.), *Een Aanvullend Archeologisch Onderzoek op vindplaats 10 binnen het plangebied 'Deest aan het Water' te Deest, gemeente Druten (Gld.)*, Groningen (ARC-publicatie 76), 39-41.

De Roller, G.J., 2004: Botanische macroresten, in J.Y. Huis in 't Veld (ed.), *Sporen uit de Vroege Bronstijd en Romeinse Tijd te Culemborg. Een archeologische opgraving van 'vindplaats B' te Lanxmeer, Culemborg, gemeente Culemborg (Gld.)*, Groningen (ARC-publicatie 97), 41-42.

De Ruyt, C., 2008: Les produits vendus au macellum, in W. Van Andringa (ed.), *Sacrifices, marché de la viande et pratiques alimentaires dans les cités du monde romain*, Turnhout (Food and History 5 (1)), 135-150.

Deschler-Erb, S., 1991: Auswertung von Tierknochenfunden der Grabung Kaiseraugst-Bireten/"Haberl" 1979.01: Speise- und Schlachtabfälle römischer Truppen in der Kaiseraugster Unterstadt der

1. Hälfte des 1. Jahrhunderts, in E. Deschler-Erb/M. Peter/S. Deschler-Erb (eds), *Das frühkasierzeitliche Militärlager in der Kaiseraugster Unterstadt,* Augst (FiA 12), 121-131.

Deschler-Erb, S., 1998: *Römische Beinartefakte aus Augusta Raurica. Rohmaterial, Technologie, Typologie und Chronologie*, Augst (FiA 27).

Deschler-Erb, S., 2006a: Leimsiederei- und Räuchereiwarenabfälle des 3. Jahrhunderts aus dem Bereich zwischen Frauenthermen und Theater von Augusta Raurica, *Jahresberichte aus Augst und Kaiseraugst* 27, 323-346.

Deschler-Erb, S., 2006b: Die Tierknochen, in C. Schucany (ed.), *Die römische Villa von Biberist-Spitalhof/SO (Grabungen 1982, 1983, 1986-1989). Untersuchungen zum Wirtschaftsteil und Überlegungen zum Umland*, Remshalden (Ausgrabungen und Forschungen 4, Band 2), 635-665.

Deschler-Erb, S., 2007: *Tiere in Asciburgium*, Duisburg (Funde aus Asciburgium 14).

Deschler-Erb, S., 2012a: Bein- und Hornverarbeitung, in H. Amrein/E. Carlevaro/E. Deschler-Erb/S. Deschler-Erb/A. Duvauchelle/L. Pernet, *Das römerzeitliche Handwerk in der Schweiz. Bestandsaufnahme und erste Synthesen*, Montagnac (Monographies instrumentum 40), 113-121.

Deschler-Erb, S., 2012b: Herstellung und Verarbeitung von Leder und Pelzen, in H. Amrein/E. Carlevaro/E. Deschler-Erb/S. Deschler-Erb/A. Duvauchelle/L. Pernet, *Das römerzeitliche Handwerk in der Schweiz. Bestandsaufnahme und erste Synthesen*, Montagnac (Monographies instrumentum 40), 127-137.

Deschler-Erb, S., 2012c: Nahrungsmittelproduktion, in H. Amrein/E. Carlevaro/E. Deschler-Erb/S. Deschler-Erb/A. Duvauchelle/L. Pernet, *Das römerzeitliche Handwerk in der Schweiz. Bestandsaufnahme und erste Synthesen*, Montagnac (Monographies instrumentum 40), 137-157.

Deschler-Erb, S., 2013: Gallische Schinken und Würste neu aufgetischt, *Jahrbuch Archäologie Schweiz* 96, 146-151.

Deschler-Erb, S./Ö. *Akeret, 2011: Archäobiologische Forschungen zum römischen Legionslager von Vindonissa und seinem Umland: Status quo und Potenzial, Jahresberichte der Gesellschaft Pro Vindonissa* 2010, 13-36.

Deschler-Erb, S./M. Groot, in press: Think global, act local: Regionalism and the supply of meat to the Roman army, in M. Allen/M. Blagg-Newsome (eds), *People and animals in the Western Roman Empire: zooarchaeological approaches to provincial culture and economy*, Portsmouth, Rhode Island (Journal of Roman Archaeology Supplementary Series).

Deschler-Erb, S./S. Schröder Fartash, 1999: Tierknochen, in J. Rychener (ed.), *Der römische Gutshof in Neftenbach,* Zürich and Egg (Monographien der Kantonsarchäologie Zürich 31/1-2), 260-264.

De Vries, L.S./F.J. Laarman, 2000: *De faunaresten van terrein 8A, Houten-Loerik, opgraving ADC/ROB, 1997*, Amersfoort (Internal Report ROB).

De Vries, L.S./F.J. Laarman, 2001: Bijlage III. Archeozoölogie. Houten - Zuid, terrein 21, in W.K. Vos/J.J. Lanzing (eds), *Houten-Zuid, Het archeologisch onderzoek op terrein 21*, Bunschoten (ADC-rapport 36), 89-96.

Dielemans, L., 2013: *Wacht aan het water. VLEN3-00: archeologisch onderzoek naar sporen en vondstassemblages uit de Romeinse tijd in Vleuterweide*, Utrecht (BRA 52).

Dietler, M., 1996: Feasts and commensal politics in the political economy, in P. Wiessner/W. Schiefenhövel (eds), *Food and the status quest: an interdisciplinary perspective*, Providence, 87-125.

Dobney, K.M./ S.D. Jaques/B.G. Irving, 1996: *Of butchers and breeds: report on vertebrate remains from various sites in the city of Lincoln*, Lincoln (Lincoln Archaeological Studies 5).

Driessen, M., 2007: *Bouwen om te blijven. De topografie, bewoningscontinuïteit en monumentaliteit van Romeins Nijmegen*, Amersfoort (RAM 151).

Ebersbach, R., 2002: *Von Bauern und Rindern. Eine Ökosystemanalyse zur Bedeutung der Rinderhaltung in bäuerlichen Gesellschaften als Grundlage zur Modellbildung im Neolithikum*, Basel (Basler Beiträge zur Archäologie 15).

Ervynck, A., 2011: Everything but the leather. The search for tanneries in Flemish archaeology, in R. Thomson/Q. Mould (eds), *Leather tanneries: the archaeological evidence*, London, 103-115.

Ervynck, A./A. Vanderhoeven, 1997: Tongeren (Belgium): changing patterns of meat consumption in a roman civitas capital, *Anthropozoologica* 25-26, 457-464.

Esser, E., 2002: *Aanvullend Archeologisch Onderzoek in het tracé van de Betuweroute, vindplaats 51 Elst/Reethse Straat*, Delft (Ossicle 61)

Esser, E., 2005: Archeozoölogie, in E. Schrijer/F. Reigersman-van Lith de Jeude/W. van Zijverden/K. Esser/K. Hänninen, 2005: *Een archeologische opgraving aan de Molenkampsweg te Brakel*, Amersfoort (ADC-rapport 389), 24-27.

Esser, E., 2009a: Archeozoölogie, in A. Luksen-IJtsma (ed.), *Oudenrijnseweg. Archeologisch onderzoek van een inheems-Romeinse nederzetting uit de eerste eeuw na Chr. en een vlasrootcomplex uit de twaalfde eeuw na Chr in De Meern, gemeente Utrecht*, Utrecht (BRA 25), 73-83.

Esser, K., 2009b: Botmateriaal, in C.M.W. den Hartog (ed.), *Sportpark Terweide 2. LR41-42: Archeologisch onderzoek Sportpark Terweide*, Utrecht (BRA 18), 119-122.

Esser, E., 2012: *De dierlijke resten uit de vicus*, Delft (Unpublished report Archeoplan Eco).

Esser, E., 2013: Archeozoölogisch onderzoek, in L. Dielemans (ed.), *Wacht aan het water. VLEN3-00: archeologisch onderzoek naar sporen en vondstassemblages uit de Romeinse tijd in Vleuterweide*, Utrecht (BRA 52), 83-98.

Esser, K./B. Beerenhout, 2006: *Voedsel en vee uit Romeins Hogeweide*, Delft (Ossicle 109).

Esser, E./B. Beerenhout/W. Kuijper, 2007: Dierlijk bot, visresten en schelpen. De wacht aan tafel, in J.S. van der Kamp (ed.), *Vroege wacht. LR31 Zandweg: archeologisch onderzoek van twee eerste-eeuwse houten wachttorens in Leidsche Rijn*, Utrecht (BRA 16), 144-158.

Esser, E./J. van Dijk, 2004: *Dierlijke resten uit de opgravingen bij Arnhem-Schuytgraaf*, Delft (Ossicle 91).

Esser, E./J. van Dijk/M. Groot, 2010: Archeozoölogisch onderzoek, in H.A.P. Veldman/E. Blom (eds), *Onder de zoden van Zaltbommel,* Amersfoort (ADC Monografie 8), 201-231.

Filean, E.P., 2006: *Domestic cattle and economic change in the Roman period Lower Rhineland: the civitas Batavorum*, Iowa (PhD thesis University of Iowa).

Filean, E.P., 2008: A biometric perspective on the size of cattle in Roman Nijmegen, the Netherlands: implications for the supply of urban consumers and the Roman army, in S. Stallibrass/R. Thomas (eds), *Feeding the Roman Army: the Archaeology of Production and Supply in the North-West Roman provinces,* Oxford, 99-115.

Filgis, M.N., 1988: Neue Funde...: Bad Wimpfen, Kreis Heilbronn, *Archäologie in Deutschland* 3 (Juli-Sept.), 44-45.

Fock, J., 1966: *Metrische Untersuchungen an Metapodien einiger europäischer Rinderrassen*, München (PhD thesis University of München).

Fokma, A., 2005: *Verslag van het archeobotanisch onderzoek van monsters uit de opgraving Tiel-Passewaaij 1997, 1999, 2000 en 2004*, Amsterdam (Internal Report VU University Amsterdam).

Grant, A., 1982: The use of tooth wear as a guide to the age of domestic ungulates, in B. Wilson/C. Grigson/S. Payne (eds), *Ageing and sexing animal bones from archaeological sites*, Oxford (BAR Brit. Ser. 109), 91-108.

Groenman-van Waateringe, W., 1983: The disastrous effect of the Roman occupation, in R.W. Brandt/J. Slofstra (eds), *Roman and Native in the Low Countries*, Oxford (BAR Int. Ser. 184), 147-57.

Groenman-van Waateringe, W., 2009: The source of hides and skins for Roman army equipment, in W.S. Hanson (ed.), *The army and frontiers of Rome. Papers offered to David J. Breeze on the occasion of his sixty-fifth birthday and his retirement from Historic Scotland*, Portsmouth, Rhode Island (JRA Supplementary Series 74), 209-215.

Groenman-van Waateringe, W./J.-P. Pals, 1994: De vegetatie op en rondom het heiligdom, in N. Roymans/T. Derks (eds), *De tempel van Empel. Een Hercules-heiligdom in het woongebied van de Bataven*, 's-Hertogenbosch (Graven naar het Brabantse Verleden 2), 72-81.

Grønlund Evers, K., 2011: *The Vindolanda tablets and the ancient economy*, Oxford (BAR Brit. Ser. 544).

Groot, M., 2002: Bijlage 6: archeozoölogisch onderzoek, in E.M.P. Verhelst (ed.), *Aanvullend archeologisch onderzoek in het tracé van de Betuweroute, vindplaats 52 Geldermalsen/Rijs en Ooyen*, Amersfoort (RAM 43), 63-66.

Groot, M., 2005a: Bot, in M. Schurmans (ed.), *Opgraving Houten-Hofstad Diepriool terrein 16*, Amsterdam (ZAR 23), 52-60.

Groot, M., 2005b: Archeozoölogie, in S. Heeren (ed.), *Een nederzetting uit de Romeinse tijd te Tiel-Bedrijvenpark. Medel-Rotonde (vindplaats 6)*, Amsterdam (ZAR 26), 53-70.

Groot, M., 2005c: Palaeopathological evidence for draught cattle on a Roman site in the Netherlands, in J. Davies/M. Fabis/I. Mainland/M. Richards/R. Thomas (eds), *Diet and Health in Past Animal Populations: Current Research and Future Directions*, Oxford, 52-57.

Groot, M., 2008a: *Animals in ritual and economy in a Roman frontier community. Excavations in Tiel-Passewaaij*, Amsterdam (AAS 12).

Groot, M., 2008b: Surplus production of animal products for the Roman army in a rural settlement in the Dutch River Area, in S. Stallibrass/R. Thomas (eds), *Feeding the Roman Army: the Archaeology of Production and Supply in the North-West Roman provinces,* Oxford, 83-98.

Groot, M., 2008c: Archeozoölogie, in M. Schurmans (ed.), *Twee nederzettingen op de grens van het Romeinse rijk. Opgraving Huissen Loostraat-Zuid*, Amsterdam (ZAN 139), 103-117.

Groot, M., 2009a: Dierlijk bot en speciale deposities met dierlijk bot, in J. van Renswoude/J. Van Kerckhove (eds), *Opgravingen in Geldermalsen-Hondsgemet. Een inheemse nederzetting uit de Late IJzertijd en Romeinse tijd*, Amsterdam (ZAR 35), 355-409.

Groot, M., 2009b: Zoöarcheologie, in M. Schurmans (ed.), *Opgraving Druten-Wilhelminastraat. Romeinse sporen in de periferie van de vindplaats Druten-Klepperhei*, Amsterdam (ZAN 174), 30-37.

Groot, M., 2010a: Het botmateriaal uit de vicus en de inheemse nederzetting, in M.C.M. Langeveld/A. Luksen-IJtsma/P. Weterings (eds), *Een goede buur? LR46 en LR49: definitief archeologisch onderzoek naar de vicus, grafvelden, infrastructuur en een inheemse nederzetting in de omgeving van het Romeinse castellum in De Meern, deelgebied 'De Woerd' (Gemeente Utrecht)*, Utrecht (BRA 19), 259-268.

Groot, M., 2010b: *Handboek zoöarcheologie*, Amsterdam (Materiaal & Methoden 1).

Groot, M., 2011a: Dierlijk bot, in J. Aarts/S. Heeren (eds), *Het grafveld aan de Passewaaijse Hogeweg. Opgravingen bij Tiel-Passewaaij 2*, Amsterdam (ZAR 41), 81-100.

Groot, M., 2011b: Household specialisation in horse breeding: the role of returning veterans in the Batavian river area, in R. Wiegels/G.A. Lehmann/G. Moosbauer (eds): *Fines imperii - imperium sine fine? Römische Okkupations- und Grenzpolitik im frühen Prinzipat*, Rahden/Westf. (Osnabrücker Forschungen zu Altertum und Antikerezeption 14), 203-218.

Groot, M., 2012a: Bot, in E.M.P. Verhelst (ed.), *Plangebied Ingen-Het Woud, Gemeente Buren. Archeologisch vooronderzoek: een inventariserend veldonderzoek (proefsleuven)*, Weesp (RAAP-rapport 2513), 64-66.

Groot, M., 2012b: Animal bones as a tool for investigating social and economic change: horse-breeding veterans in the *civitas Batavorum,* in I. Schrufer-Kolb (ed.), *More than Just Numbers? The role of science in Roman archaeology*, Portsmouth, Rhode Island (JRA Supplementary Series 91), 71-92.

Groot, M., 2013a: Dierlijk bot, in R.W. de Groot (ed.), *Een kijkje in het rijksmonument Merm-Wolfhoeksestraat te Elst. Aardgastransportleidingtracé Angerlo-Beuningen (A-663), catalogusnummer 10. Gemeente Overbetuwe. Archaeologisch onderzoek: opgraving*, Weesp (RAAP-rapport 2347), 115-119.

Groot, M., 2013b: Een Romeinse eikelmuis uit Hoogeloon, *Cranium*, 8-12.

Groot in press a: Dierlijk bot, in L. van der Feijst (ed.), *Klein Sonsbeek, een nederzetting uit de IJzertijd te Werkhoven,* Amersfoort (ADC-rapport 100).

Groot, M., in press b: Animal health in the Late Iron Age and Roman Dutch River Area, in R. Thomas/T. Antikas (eds), *Animal Diseases in Past Human Societies: Proceedings of the Fourth ICAZ Animal Paleopathology Working Group*, Atlanta, GA.

Groot, M./L.I. Kooistra, 2009: Land use and the agrarian economy in the Roman Dutch River Area, *Internet Archaeology* 27 (http://intarch.ac.uk/journal/issue27/5/1.html).

Groot, M./S. Heeren/L. Kooistra/W. Vos, 2009: Surplus production for the market? The agrarian economy in the non-villa landscapes of Germania Inferior, *JRA* 22, 231-252.

Groot, M./A. Ervynck/F. Pigière, 2011: Vagrant vultures: archaeological evidence for the cinereous vulture (*Aegypius monachus*) in the Low Countries, in W. Prummel/J.T. Zeiler/D.C. Brinkhuizen (eds), *Birds in Archaeology. Proceedings of the 6th Meeting of the ICAZ Bird Working Group in Groningen (23.8 - 27.8.2008)*, Groningen (Groningen Archaeological Studies 12), 241-251.

Groot, M./D. Lentjes, 2013: Studying subsistence and surplus production, in M. Groot/D. Lentjes/J. Zeiler (eds), *Barely surviving or more than enough? The environmental archaeology of subsistence, specialisation and surplus food production*, Leiden, 7-27.

Groot, M./A. Robeerst, 2014: Dierlijk bot, in R.P.J. Kloosterman/M. Polak/M. Zandstra (eds), *Opgravingen op het terrein van het voormalige Canisiuscollege in Nijmegen, 1987-1997*, *Vondsten uit castra en canabae, I,* Nijmegen (Auxiliaria 14), 261-295.

Groot, M./S. Deschler-Erb, 2015: Market strategies in the Roman provinces: Different animal husbandry systems explored by a comparative regional approach, *Journal of Archaeological Science: Reports* 4, 447-460.

Groot, M./S. Deschler-Erb, 2016: Carnem et circenses - consumption of animals and their products in Roman urban and military sites in two regions in the northwestern provinces, *Environmental Archaeology: the Journal of Human Palaeoecology.*

Haalebos, J.K., 1996: Opgravingen op het terrein van het voormalige Canisiuscollege 1994-1996, *Numaga* 43, 7-41.

Haalebos, J.K., 1993: Castra en canabae. Opgravingen op het terrein van het voormalige Canisiuscollege 1987-1992, *Numaga* 40, 7-36.

Haalebos, J.K./A.E. de Hingh/L.I. Kooistra, 1994: Opgravingen op het terrein van het voormalige Canisiuscollege 1993, *Numaga* 41, 10-34.

Haalebos, J.K. *et al.*, 1995: *Castra und Canabae: Ausgrabungen auf dem Hunerberg in Nijmegen 1987-1994*, Nijmegen.

Haalebos, J.K. *et al.*, 1998: *Centuriae onder Centuriae Hof. Opgravingen achter het hoofdgebouw van het voormalige Canisiuscollege te Nijmegen, 1995-1997*, Nijmegen.

Habermehl, K.H., 1975: *Die Altersbestimmung bei Haus- und Labortieren*, Berlin.

Halici, H., 2004a: Faunaresten, in A. Nieuwhof (ed.), *Een definitief archeologisch onderzoek (DAO) van de Romeinse vindplaats Deest 10, gemeente Druten (Gld.)*, Groningen (ARC-publicatie 93), 67-76.

Halici, H., 2004b: Faunaresten, in J.Y. Huis in 't Veld (ed.), *Sporen uit de Vroege Bronstijd en Romeinse Tijd te Culemborg. Een archeologische opgraving van 'vindplaats B' te Lanxmeer, Culemborg, gemeente Culemborg (Gld.)*, Groningen (ARC-publicatie 97), 37-40.

Halstead, P., 1985: A study of mandibular teeth from Romano-British contexts at Maxey, in F. Pryor/C. French/D. Crowther/D. Gurney/G. Simpson/M. Taylor (eds), *Archaeology and environment in the lower Welland valley, volume 1*, Cambridge (East Anglian Archaeology Report 27), 219-224.

Halstead, P./J. O'Shea, 1989: *Bad year economics: cultural responses to risk and uncertainty*, Cambridge.

Hambleton, E., 1999: *Animal husbandry regimes in Iron Age Britain. A comparative study of faunal assemblages from British Iron Age sites*, Oxford (BAR Brit. Ser. 282).

Hänninen, K., 2005a: Botanisch materiaal, in M. Schurmans (ed.), *Opgraving Houten-Hofstad Dieprioolterrein 16*, Amsterdam (ZAR 23), 60-65.

Hänninen, K., 2005b: Archeobotanische resten, in E. Schrijer/F. Reigersman-van Lith de Jeude/W. van Zijverden/K. Esser/K. Hänninen, 2005: *Een archeologische opgraving aan de Molenkampsweg te Brakel*, Amersfoort (ADC-rapport 389), 22-23.

Hänninen, K./C. Vermeeren, 1997: *Exotische offers. Botanisch onderzoek aan kuilen uit de Romeinse Fortuna-tempel op het Maasplein in Nijmegen*, Zaandam (BIAX*iaal* 51).

Hänninen, K. /L. Kooistra, 2008: Archeobotanie, in M. Schurmans (ed.), 2008: *Twee nederzettingen op de grens van het Romeinse rijk. Opgraving Huissen Loostraat-Zuid*, Amsterdam (ZAN 139), 118-125.

Hayden, B., 1996: Feasting in prehistoric and traditional societies, in P. Wiessner/W. Schiefenhövel (eds), *Food and the status quest: an interdisciplinary perspective*, Providence, 127-149.

Hazen, P./W. Roessingh, 2010: Sporen en structuren, in E. Blom/W. Roessingh (eds), *Heteren Uilenburg: 1500 jaar bewoning op een crevasse*, Amersfoort (ADC-rapport 1664), 31-68.

Heeren, S., 2005: *Een nederzetting uit de Romeinse tijd te Tiel-Bedrijvenpark. Medel-Rotonde (vindplaats 6)*, Amsterdam (ZAR 26).

Heeren, S., 2006: *Opgravingen bij Tiel-Passewaaij 1. De nederzetting aan de Passewaaijse Hogeweg*, Amsterdam (ZAR 29).

Heeren, S., 2009: *Romanisering van rurale gemeenschappen in de civitas Batavorum. De casus Tiel-Passewaaij*, Amersfoort (NAR 36).

Heeren, S., in prep: *De voorgeschiedenis en opkomst van Dorestad. Wijk bij Duurstede-De Geer en de bewoning in de microregio van de tweede tot de negende eeuw*, Amersfoort (NAR).

Heeren, S./P. Hoff/T. Derks, 2008: Sporen en structuren, in T. Derks/J. Van Kerckhove/P. Hoff (eds), *Nieuw archeologisch onderzoek rond de Grote Kerk van Elst, gemeente Overbetuwe (2002-2003)*, Amsterdam (ZAR 31), 29-63.

Hendriksen, M., 2009: De metalen voorwerpen, in C.M.W. den Hartog, *Sportpark Terweide 2. LR41-42: Archeologisch onderzoek Sportpark Terweide*, Utrecht (BRA 18), 67-111.

Hesse, R., 2011: Reconsidering animal husbandry and diet in the northwestern provinces, *JRA* 24, 215-248.

Hessing, W.A.M., 2001: Paardenfokkers in het grensgebied. De Bataafse nederzetting op De Woerd bij Kesteren, in A. Carmiggelt (ed.), *Opgespoord verleden. Archeologie in de Betuweroute*, Abcoude, 142-172.

Higham, C.F.W., 1967: Stock rearing as a cultural factor in prehistoric Europe, *Journal of the Prehistoric Society* 6, 84-107.

Hoek, R.G.J.M., 1988: Een kuil met slachtafval, in J.E. Bogaers/J.K. Haalebos, Opgravingen op het terrein van het voormalige Canisiuscollege, 1987, *Numaga* 35, 39-40.

Hoek, R.G.J.M./D.C. Brinkhuizen, 1990: Zoogdieren, vogels en vissen, in J.E. Bogaers/J.K. Haalebos, Opgravingen op het terrein van het voormalige Canisiuscollege, 1989, *Numaga* 37, 81-83.

Hogestijn, J.W.H., 1984: *Een palaeobotanische analyse van enkele monsters uit waterputten in de nederzettingen te Houten-Doornkade en Bunnik-Marsdijk (Prov. Utrecht)*, Amsterdam (Internal Report IPP, University of Amsterdam).

Howard, M, 1963: The metrical determination of the metapodials and skulls of cattle, in A.E. Mourant/F.E. Zeuner (eds), *Man and cattle*, London (Occasional Paper of the Royal Anthropological Institute 18), 92-100.

Huis in 't Veld, J.Y., 2004: *Sporen uit de Vroege Bronstijd en Romeinse Tijd te Culemborg. Een archeologische opgraving van 'vindplaats B' te Lanxmeer, Culemborg, gemeente Culemborg (Gld.)*, Groningen (ARC-publicatie 97).

Huisman, M.A./C.G. Koopstra, 2004: Metaal, in A. Nieuwhof (ed.), *Een definitief archeologisch onderzoek (DAO) van de Romeinse vindplaats Deest 10, gemeente Druten (Gld.)*, Groningen (ARC-publicatie 93), 33-47.

Hulst, R.S., 1978: Druten-Klepperhei, Vorbericht der Ausgrabungen einer römischen Villa, *BROB*, 133-151.

Hulst, R.S., 1980: Een Romeinse villa bij Druten, *Hermeneus* 52, 117-127.

Hulst, R.S./C. van Duijn/J.W. Noordam, 1973: Ewijk, gem. Ewijk (Gld.). Bewoning IJzertijd en

Romeinse Tijd, *JROB*, 15-16.
Hulst, R.S./J.W. Noordam, 1974: Ewijk, gem. Ewijk (Gld.). Bewoning uit Neolithicum, IJzertijd en Romeinse Tijd, *JROB*, 9-10.
Hulst, R.S./ J.W. Noordam, 1977a: Ewijk, gem. Ewijk (Gld.). Bewoning Romeinse Tijd, *JROB*, 31-32.
Hulst, R.S./J.W. Noordam, 1977b: Kesteren, gem. Kesteren (Gld.). Nederzetting Romeinse Tijd, *JROB*, 32.
Hulst, R.S./K. Greving/W. van Arler, 1984: Kesteren, gem. Kesteren. Nederzetting (vicus) Romeinse Tijd, *JROB*, 29-30.
Hyland, A., 1990: *Equus: the horse in the Roman world*, London.
Johnstone, C.J., 2004: *A biometric study of equids in the Roman world*, York (PhD thesis University of York).
Johnstone, C., 2008: Commodities or logistics? The role of equids in Roman supply networks, in S. Stallibrass/R. Thomas (eds), *Feeding the Roman Army: the Archaeology of Production and Supply in NW Europe,* Oxford, 128-145.
Junkelmann, M., 1990: *Die Reiter Roms. Teil I: Reise, Jagd, Triumph und Circusrennen*, Mainz am Rhein.
Junkelmann, M., 1991: *Die Reiter Roms. Teil II: Der militärische Einsatz*, Mainz am Rhein.
Kalis, A.J./S. Karg/J. Meurers-Balke/H. Teunissen-Van Oorschot, 2008: Mensch und Vegetation am Unteren Niederrhein wärend der Eisen- und Römerzeit, in S. Ristow (ed.), *Colonia Ulpia Traiana*, Mainz am Rhein (Geschichte der Stadt Xanten 1), 31-48.
Kemmers, F., 2008: Munten, in M. Schurmans (ed.), *Twee nederzettingen op de grens van het Romeinse rijk. Opgraving Huissen Loostraat-Zuid*, Amsterdam (ZAN 139), 85-95.
Kemmers, F., 2011: Munten, in W. Roessingh/E. Blom (eds), *Boeren of reizigers langs de limes bij Huissen?*, Amersfoort (ADC-rapport 1569), 83-90.
Kerkhoven, N.D., 2011: Metaal, in P.G.H. Weterings/Y. Meijer (eds), *Op zoek naar de weg. LR60: onderzoek naar de Romeinse limesweg in De Meern (gemeente Utrecht)*, Utrecht (BRA 33), 59-72.
Kerkhoven, N.D., 2013: Metaal, in L. Dielemans (ed.), *Wacht aan het water. VLEN3-00: archeologisch onderzoek naar sporen en vondstassemblages uit de Romeinse tijd in Vleuterweide*, Utrecht (BRA 52), 119-127.
King, A., 1984: Animal bones and the dietary identity of military and civilian groups in Roman Britain, Germany and Gaul, in T.F.C. Blagg/A.C. King (eds), *Military and civilian in Roman Britain. Cultural relationships in a frontier province*, Oxford (BAR Brit. Ser. 136), 187-217.
King, A., 1999: Meat diet in the Roman world: a regional inter-site comparison of the mammal bones, *JRA* 12, 168-202.
King, A., 2005: Animal remains from temples in Roman Britain, *Britannia* 36, 329-369.
Kloosterman, R.P.J./M. Polak/M. Zandstra, 2014: *Opgravingen op het terrein van het voormalige Canisiuscollege in Nijmegen, 1987-1997, Vondsten uit castra en canabae, I,* Nijmegen (Auxiliaria 14).
Knol, E., 1983: Farming on the banks of the river Aa. The faunal remains and bone objects of Paddepoel 200 B.C.-250 A.D., *Palaeohistoria* 25, 145-182.
Kokabi, M./S. Frey, 1988: Neue Funde...: Bad Wimpfen, Kreis Heilbronn, *Archäologie in Deutschland* 3 (Juli-Sept.), 43-44.
Kolling, A., 1986: Zum Bilch Siebenschläfer, *Germania* 64 (2), 584-588.
Kooistra, L.I., 1989: Botanische resten uit een kuil, in J.E. Bogaers/J.K. Haalebos, Opgravingen op het terrein van het voormalige Canisiuscollege, 1988, *Numaga* 36 (3-4), 58-59.
Kooistra, L.I., 1996: *Borderland farming. Possibilities and limitations of farming in the Roman period and Early Middle Ages between the Rhine and Meuse*, Assen/Amersfoort.
Kooistra, L.I., 2007: Botanische materialen, in E. Verhelst/M. Schurmans (eds), *Oudheden uit Odijk. Bewoningssporen uit de Late IJzertijd, Romeinse tijd en Merovingische tijd aan de Singel West/Schoudermantel*, Amsterdam (ZAR 30), 181-210.
Kooistra, L.I., 2008: *Utrecht-De Meern (LR58). Sporen van een vroeg- en midden-Romeinse vicus onderzocht*

op botanische resten, Zaandam (BIAX*iaal* 380).

Kooistra, L.I., 2009a: Botanische materialen, in J. van Renswoude/J. Van Kerckhove (eds), *Opgravingen in Geldermalsen-Hondsgemet. Een inheemse nederzetting uit de Late IJzertijd en Romeinse tijd*, Amsterdam (ZAR 35), 411-457.

Kooistra, L.I., 2009b: Archeobotanie, in M. Schurmans (ed.), *Opgraving Druten-Wilhelminastraat. Romeinse sporen in de periferie van de vindplaats Druten-Klepperhei*, Amsterdam (ZAN 174), 38-45.

Kooistra, L.I., 2009c: The provenance of cereals for the Roman army in the Rhine delta, based on archaeobotanical evidence, *Beihefte der Bonner Jahrbücher* 58 (1), 219-237.

Kooistra, L.I., 2010: Archeo-botanisch onderzoek naar de resten uit de inheemse nederzetting en de *vicus*, in M.C.M. Langeveld/A. Luksen-IJtsma/P. Weterings (eds), *Een goede buur? LR46 en LR49: definitief archeologisch onderzoek naar de vicus, grafvelden, infrastructuur en een inheemse nederzetting in de omgeving van het Romeinse castellum in De Meern, deelgebied 'De Woerd' (Gemeente Utrecht)*, Utrecht (BRA 19), 275-283.

Kooistra, L.I./H. van Haaster, 2001: Archeobotanie, in M.M. Sier/C.W. Koot (eds), 2001: *Kesteren-De Woerd. Bewoningssporen uit de IJzertijd en de Romeinse tijd*, Amersfoort (RAM 82), 293-359.

Kooistra, L.I./S. Heeren, 2007: Het verhaal van een afgebrande graanschuur, in N. Roymans/T. Derks/S. Heeren (eds), *Een Bataafse gemeenschap in de wereld van het Romeinse rijk. Opgravingen te Tiel-Passewaaij*, Utrecht, 167-176.

Kooistra, L.I./M. van Dinter/M.K. Dütting/P. van Rijn/C. Cavallo, 2013: Could the local population of the Lower Rhine delta supply the Roman army? Part 1: The archaeological and historical framework, *JALC* 4 (2), 5-23.

Koopmans, L., 1996: *Vroeg-Romeins botmateriaal van de Hunerberg te Nijmegen*, Amsterdam (Student's dissertation University of Amsterdam).

Kootker, L., 2010: *Dierlijk botmateriaal uit Lingewaard, plangebied Agropark II*, Delft (Ossicle 193).

Koster, A.A./I. Joosten, 2001: Metaal en metaalbewerking, in M.M. Sier/C.W. Koot (eds), *Kesteren-De Woerd. Bewoningssporen uit de IJzertijd en de Romeinse tijd*, Amersfoort (RAM 82), 183-207.

Kreuz, A., 2005: Landwirtschaft im Umbruch? Archäobotanische Untersuchungen zu den Jahrhunderten um Christi Geburt in Hessen und Mainfranken, *Bericht der Römisch-Germanischen Kommission* 85, 97-292.

Krist, J.S./J.B. de Voogd/J. Schoneveld, 2001: *Een vindplaats uit de Late IJzertijd en Vroeg-Romeinse tijd aan de Schalkwijkseweg te Houten, terrein 14, Provincie Utrecht*, Groningen (ARC-publicatie 48).

Krist, J.S., 2003: *Een Aanvullend Archeologisch Onderzoek op vindplaats 10 binnen het plangebied 'Deest aan het Water' te Deest, gemeente Druten (Gld.)*, Groningen (ARC-publicatie 76).

Kubiak-Martens, L., 2005: Verkoold voedsel, in H. van Enckevort/J. Thijssen (ed.), *In de schaduw van het Noorderlicht. Een Gallo-Romeinse tempel te Elst-Westeraam*, Abcoude, 89-92.

Küchelmann, H.C., 2013: Tierknochen aus der Siedlung der Vorrömischen Eisenzeit und Römischen Kaiserzeit Bentumersiel bei Jemgum, Ldkr. Leer (Ostfriesland), *Siedlungs- und Küstenforschung im südlichen Nordseegebiet* 36, 63-85.

Kunst, G.K., 2006: Oberflächenmarken an provincialrömischen Tierknochen - ein Hinweis zur Fleischkonservierung?, *BAPA 5*, 62-69.

Laarman, F.J., 1987: In de put zitten .... (1); dierlijke overblijfselen uit een Romeinse waterput, in E.J. Bult/D.P. Hallewas (eds), *Graven bij Valkenburg II; het archeologisch onderzoek in 1986*, Delft, 51-55.

Laarman, F.J., 1996a: The zoological remains, in L.I. Kooistra, *Borderland farming*, Amersfoort, 343-357.

Laarman, F.J., 1996b: Zoological material of the Bronze Age, Iron Age and Roman period from Wijk bij Duurstede-De Horden, in L.I. Kooistra, *Borderland farming*, Amersfoort, 369-380.

Lange, A.G., 1990: *De Horden near Wijk bij Duurstede. Plant remains from a native settlement at the Roman frontier: a numerical approach*. Amersfoort (NO 13).

Langeveld, M., 2010a: Conclusie, in M. Langeveld/A. Luksen-IJtsma/P. Weterings (eds), *Een goede buur? LR46 en LR49: definitief archeologisch onderzoek naar de vicus, grafvelden, infrastructuur en een inheemse nederzetting in de omgeving van het Romeinse castellum in De Meern, deelgebied 'De Woerd' (Gemeente Utrecht)*, Utrecht (BRA 19), 317-328.

Langeveld, M., 2010b: Een voorhoofdband van een ruiterhelm uit de inheemse nederzetting, in M. Langeveld/A. Luksen-IJtsma/P. Weterings (eds), *Een goede buur? LR46 en LR49: definitief archeologisch onderzoek naar de vicus, grafvelden, infrastructuur en een inheemse nederzetting in de omgeving van het Romeinse castellum in De Meern, deelgebied 'De Woerd' (Gemeente Utrecht)*, Utrecht (BRA 19), 297-304.

Langeveld, M.C.M., 2010c: De westelijke wachttoren, in M.C.M. Langeveld/A. Luksen-IJtsma/E.P. Graafstal, *Wegens wateroverlast. LR 39 De Balije II: wachttorens, rivierdynamiek en Romeinse infrastructuur in een rivierbocht van de Heldammer Stroom*, Utrecht (BRA 11), 51-71.

Langeveld, M.C.M., 2010d: Metaal, in H.A.P. Veldman/E. Blom, *Onder de zoden van Zaltbommel,* Amersfoort (ADC Monografie 8), 171-190.

Langeveld, M.C.M., in prep.: *Vicuslaan (LR58),* Utrecht (BRA 32).

Langeveld, M.C.M./A. Luksen-IJtsma/E.P. Graafstal, 2010a: *Wegens wateroverlast. LR 39 De Balije II: wachttorens, rivierdynamiek en Romeinse infrastructuur in een rivierbocht van de Heldammer Stroom*, Utrecht (BRA 11).

Langeveld, M./A. Luksen-IJtsma/P. Weterings, 2010b: *Een goede buur? LR46 en LR49: definitief archeologisch onderzoek naar de vicus, grafvelden, infrastructuur en een inheemse nederzetting in de omgeving van het Romeinse castellum in De Meern, deelgebied 'De Woerd' (Gemeente Utrecht)*, Utrecht (BRA 19).

Lauwerier, R.C.G.M., 1988: *Animals in Roman times in the Dutch Eastern River Area*, Amersfoort (NO 12).

Lauwerier, R.C.G.M., 1990: *Dierlijk bot uit twee grafvelden uit de Romeinse tijd in Cuijk*, Amersfoort (Internal report ROB).

Lauwerier, R.C.G.M., 1993: Twenty-eight bird briskets in a pot: Roman preserved food from Nijmegen, *Archaeofauna* 2, 15-19.

Lauwerier, R.C.G.M., 1999: Eating horsemeat: the evidence in the Roman Netherlands, *Archaeofauna* 8, 101-113.

Lauwerier, R.C.G.M., 2009: Animal husbandry and fishing, in W.J.H. Willems/H. van Enckevort, *Ulpia Noviomagus. Roman Nijmegen: The Batavian capital at the imperial frontier*, Portsmouth, Rhode Island (JRA Supplementary Series 73), 158-164.

Lauwerier, R.C.G.M./W.A.M. Hessing, 1992: Men, horses and the Miss Blanche effect: Roman horse burials in a cemetery at Kesteren, the Netherlands, *Helinium* 32 (1-2), 78-109.

Lauwerier, R.C.G.M./G. IJzereef, 1998: Livestock and meat from the Iron Age and Roman period settlements at Oss-Ussen (800 BC – AD 250), in H. Fokkens (ed.), *The Ussen project. The first decade of excavations at Oss*, Leiden (Analecta Praehistorica Leidensia 30), 349-367.

Lauwerier, R.C.G.M./J.M.M. Robeerst, 2001: Horses in the Roman times in the Netherlands, in H. Buitenhuis/W. Prummel (eds), *Animals and Man in the Past*, Groningen (ARC-publicatie 41), 275-290.

Lauwerier, R.C.G.M./C. Wouda/L. de Groot, 2005: Bot uit Romeins Bodegraven, *Westerheem* 54 (6), 300-306.

Legge, A.J., 1981: Aspects of cattle husbandry, in R.J. Mercer (ed.), *Farming practice in British prehistory*, Edinburgh, 169-181.

Lentacker, A./A. Ervynck/W. Van Neer, 2004: The symbolic meaning of the cock. The animal remains from the *Mithraeum* at Tienen (Belgium), in M. Martens/G. De Boe (eds), *Roman Mithraism: the evidence from the small finds*, Brussels (Archeologie in Vlaanderen 4), 57-80.

Lepetz, S., 1996: *L'animal dans la société Gallo-romaine de la France du Nord*, Amiens.

Levine, M.A., 1982: The use of crown height measurements and eruption-wear sequences to age horse teeth, in B. Wilson/C. Grigson/S. Payne (eds), *Ageing and sexing animal bones from archaeological sites*,

Oxford (BAR Brit. Ser. 109), 223-250.
Lucas, A.T., 1989: *Cattle in ancient Ireland*, Kilkenny (Studies in Irish Archaeology and History).
Luff, R.M., 1982: *A zooarchaeological study of the Roman north-western provinces*, Oxford (BAR Int. Ser. 137).
Luksen-IJtsma, A., 2009: *Oudenrijnseweg. Archeologisch onderzoek van een inheems-Romeinse nederzetting uit de eerste eeuw na Chr. en een vlasrootcomplex uit de twaalfde eeuw na Chr in De Meern, gemeente Utrecht*, Utrecht (BRA 25).
Luksen-IJtsma, A., 2010: *De limesweg in West-Nederland. Inventarisatie, analyse en synthese van archeologisch onderzoek naar de Romeinse weg tussen Vechten en Katwijk*, Utrecht (BRA 40).
MacGregor, A., 1989: Bone, antler and horn industries in the urban context, in D. Serjeantson/T. Waldron (eds), *Diet and crafts in towns. The evidence of animal remains from the Roman to the Post-Medieval periods*, Oxford (BAR Brit. Ser. 199), 107-128.
MacKinnon, M., 2004: *Production and consumption of animals in Roman Italy: integrating the zooarchaeological and textual evidence*, Portsmouth, Rhode Island (JRA Supplementary Series 54).
MacKinnon, M., 2010: Cattle 'breed' variation and improvement in Roman Italy: connecting the zooarchaeological and ancient textual evidence, *World Archaeology* 42 (1), 55-73.
Maltby, M., 1989: Urban-rural variations in the butchering of cattle in Romano-British Hampshire, in D. Serjeantson/T. Waldron (eds), *Diet and crafts in towns. The evidence of animal remains from the Roman to the post-medieval periods*, Oxford (BAR Brit. Ser. 199), 75-106.
Maltby, M., 1994: The meat supply in Roman Dorchester and Winchester, in A.R. Hall/H.K. Kenward (eds), *Urban-rural connexions: perspectives from environmental archaeology*, Oxford, 85-102.
Maltby, M., 1997: Domestic fowl on Romano-British sites: inter-site comparisons of abundance, *IJO* 7, 402-414.
Maltby, M., 2010: *Feeding a Roman town. Environmental evidence from excavations in Winchester, 1972-1985*, Winchester.
Martens, M., 2012: *Life and culture in the Roman small town of Tienen. Transformations of cultural behavior by comparative analysis of material culture assemblages*, Amsterdam (PhD thesis VU University Amsterdam).
Matolcsi, J., 1970: Historische Enforschung der Körpergrösse des Rindes auf Grund von ungarischem Knochenmaterial, *Zeitschrift für Tierzüchtung und Züchtungsbiologie* 87, 89-137.
May, E., 1985: Wideristhöhe und Langknochenmaße bei Pferden – ein immer noch aktuelles Problem, *Zeitschrift für Säugetierkunde* 50, 368-382.
McCormick, F., 1992: Early faunal evidence for dairying, *Oxford Journal of Archaeology* 11 (2), 201-209.
Meadow, R.H., 1999: The use of size index scaling techniques for research on archaeozoological collections from the Middle East, in C. Becker/H. Manhart/J. Peters/J. Schibler (eds), *Historia Animalium ex Ossibus. Festschrift für Angela von den Driesch*, Rahden/Westf., 285-300.
Meijer, Y., 2009a: *Gewei uit de geul. LR57: Onderzoek naar een bronstijdrestgeul en sporen uit de vroeg-Romeinse tijd aan de Burgemeester Middelweerdbaan in De Meern, Utrecht*, Utrecht (BRA 31).
Meijer, Y., 2009b: Archeozoölogie, in Y. Meijer (ed.), *Gewei uit de geul. LR57: Onderzoek naar een bronstijdrestgeul en sporen uit de vroeg-Romeinse tijd aan de Burgemeester Middelweerdbaan in De Meern, Utrecht*, Utrecht (BRA 31), 137-146.
Meijer, Y., 2011: Archeozoölogie, in P.G.H. Weterings/Y. Meijer (eds), *Op zoek naar de weg. LR60: onderzoek naar de Romeinse limesweg in De Meern (gemeente Utrecht)*, Utrecht (BRA 33), 105-124.
Méniel, P., 1985: Les animaux, in J.L. Brunaux/P. Méniel/F. Poplin, *Gournay I. Les fouilles sur le sanctuaire et l`oppidum (1975-1984)*, Amiens (Revue Archéologique de Picardie Numéro spécial 180), 125-146.
Méniel, P., 2001: *Les Gaulois et les animaux: élevage, repas et sacrifices*, Paris.
Minniti, C./S. Valenzuela-Lamas/J. Evans/U. Albarella, 2014: Widening the market. Strontium isotope analysis on cattle teeth from Owslebury (Hampshire, UK) highlights changes in livestock

supply between the Iron Age and the Roman period, *JAS* 42, 305-314.
Moolhuizen, C., 2010: Archeobotanisch onderzoek, in E. Blom/W. Roessingh (eds), *Heteren Uilenburg: 1500 jaar bewoning op een crevasse*, Amersfoort (ADC-rapport 1664), 135-137.
Moran, N.C./T.P. O'Connor, 1994: Age attribution in domestic sheep by skeletal and dental maturation: a pilot study of available resources, *IJO* 4, 267-285.
Mulkeen, S./T.P. O'Connor, 1997: Raptors in towns: towards an ecological model, *IJO* 7, 440-449.
Nicolay, J., 2007: *Armed Batavians. Use and significance of weaponry and horse gear from non-military contexts in the Rhine delta (50 BC to AD 450)*, Amsterdam (AAS 11).
Niemeijer, R., 2013: Het Romeinse gedraaide aardewerk, in L. Dielemans (ed.), *Wacht aan het water. VLEN3-00: archeologisch onderzoek naar sporen en vondstassemblages uit de Romeinse tijd in Vleuterweide*, Utrecht (BRA 52), 67-78.
Nieuwhof, A., 2004: *Een definitief archeologisch onderzoek (DAO) van de Romeinse vindplaats Deest 10, gemeente Druten (Gld.)*, Groningen (ARC-publicatie 93).
Nooijen, C./F.F.A. van der Chijs, 2002: Metaal, in E.E.B. Bulten (ed.), *IJsselstein, Lage Dijk N210*, Amersfoort (ADC-rapport 133), 70-73.
O'Connor, T.P., 1986: The garden dormouse *Eliomys quercinus* from Roman York, *Journal of Zoology* 53, 620-622.
O'Connor, T.P., 1995: Size increase in post-medieval English sheep: the osteological evidence, *Archaeofauna* 4, 81-91.
O'Connor, T.P., 2000a: *The archaeology of animal bones*, Stroud.
O'Connor, T.P., 2000b: Bones as evidence of meat production and distribution in York, in E. White (ed.), *Feeding a city: York. The provision of food from Roman times to the beginning of the twentieth century,* Devon, UK, 43-60.
O'Connor, T.P., 2007: Wild or domestic? Biometric variation in the cat *Felis silvestris* Schreber, *IJO* 17, 581-595.
Oudemans, T.F.M./L. Kubiak-Martens, 2011: Residu-analyse, in P.G.H. Weterings/Y. Meijer, 2011: *Op zoek naar de weg. LR60: onderzoek naar de Romeinse limesweg in De Meern (gemeente Utrecht)*, Utrecht (BRA 33), 91-104.
Oueslati, T., 2005: Les ossements animaux, l'archéozoologie et les professions de lálimentation dans le Nord de la Gaule romaine: le cas de la boucherie bovine, *Revue du Nord - Archéologie de la Picardie et du Nord de la France* 87 (363), 175-183.
Payne, S., 1969: A metrical distinction between sheep and goat metacarpals, in P. Ucko/G. Dimbleby (eds), *The domestication and exploitation of plants and animals*, London, 295-305.
Payne, S., 1973: Kill-off patterns in sheep and goats: the mandibles from Asvan Kale, *Anatolian Studies* 23, 281-303.
Payne, S./G. Bull, 1988: Components of variation in measurements of pig bones and teeth, and the use of measurements to distinguish wild from domestic pig remains, *Archaeozoologia* 2, 27-65.
Peters, J., 1998: *Römische Tierhaltung und Tierzucht. Eine Synthese aus archäozoologischer Untersuchung und schriftlich-bildlicher Überlieferung*, Rahden/Westf. (Passauer Universitätsschriften zur Archäologie 5).
Pigière, F./A. Lepot, 2013: Food production and exchanges in the Roman civitas Tungrorum, in M. Groot/D.M. Lentjes/J.T. Zeiler (eds), *Barely surviving or more than enough? The environmental archaeology of subsistence, specialisation and surplus food production*, Leiden, 225-246.
Pigière, F., 2014: Animal husbandry in the core area of the *civitas Tungrorum*, in N. Roymans/T. Derks/H. Hiddink (eds), *The Roman villa of Hoogeloon and the archaeology of a marginal region in the Lower Germanic frontier zone*, Amsterdam (AAS 22).
Polak, M., 2009: The Roman military presence in the Rhine delta in the period c. AD 40-140, in A. Morillo/N. Hanel/E. Martín (eds), *Limes XX, XXth International Congress of Roman Frontiers studies, Leon, (España), Septiembre 2006*, Madrid (Anejos de Gladius 13-2), 945-953.

Polak, M./L.I. Kooistra, 2015: A sustainable frontier? The establishment of the Roman frontier in the Rhine delta. Part 1: From the end of the Iron Age to the death of Tiberius (c. 50 BC-AD 37), *Jahrbuch des Römisch-Germanischen Zentralmuseums 60, 2013*, 355-458.

Prummel, W., 1974: *Dierlijke resten uit de opgraving Valkenburg 1962, de perioden I, II, III en IV en Middeleeuwen*, Groningen (Unpublished report University of Groningen).

Prummel, W., 1978: Animal bones from tannery pits of 's-Hertogenbosch, *BROB* 28, 399-422.

Prummel, W., 1979: Environment and stock-raising in Dutch settlements of the Bronze Age and Middle Ages, *Palaeohistoria* 21, 91-107

Prummel, W., 2008: Dieren op de wierde Englum, in A. Nieuwhof (ed.), *De Leege Wier van Englum. Archeologisch onderzoek in het Reitdiepgebied*, Groningen (Jaarverslagen van de Vereniging voor Terpenonderzoek 91), 116-159.

Pucher, E., 2013: Milchkühe versus Arbeitsochsen: osteologische Unterscheidungsmerkmale zwischen alpin-donauländischen und italischen Rindern zur Römischen Kaiserzeit, *BAPA* 9, 9-36.

Renes, J., 1999: *Landschappen van Maas en Peel. Een toegepast historisch-geografisch onderzoek in het streekplangebied Noord- en Midden-Limburg*, Leeuwarden.

Rixson, D., 1989: Butchery evidence on animal bones, *Circaea* 6 (1), 49-61.

Robeerst, J.M.M., 2005a: Interaction and exchange in food production in the Nijmegen frontier area during the Early Roman Period, in J. Bruhn/B. Croxford/D. Grigoropoulos (eds), *TRAC 2004: Proceedings of the Fourteenth Annual Theoretical Roman Archaeology Conference, University of Durham 26-27 March 2004,* Oxford.

Robeerst, J.M.M., 2005b: Offerdieren en Rituele maaltijden te Elst Westeraam, in H. van Enckevort/J. Thijssen (eds), *In de schaduw van het Noorderlicht. Een Gallo-Romeinse tempel te Elst-Westeraam*, Abcoude, 94-100.

Robeerst, A., 2008: Dierlijk botmateriaal, in T. Derks/J. Van Kerckhove/P. Hoff (eds), *Nieuw archeologisch onderzoek rond de Grote Kerk van Elst, gemeente Overbetuwe (2002-2003)*, Amsterdam (ZAR 31), 98-116.

Robeerst, A., unpublished: *Nijmegen in the Middle Roman period* (Manuscript of unfinished PhD thesis).

Roessingh, W., 2009: Sporen en structuren, in W. Roessingh/E. Blom (eds), *Een omgreppeld nederzettingsterrein uit de Romeinse tijd*, Amersfoort (ADC-rapport 1426), 22-50.

Roessingh, W./E. Blom, 2009: *Een omgreppeld nederzettingsterrein uit de Romeinse tijd*, Amersfoort (ADC-rapport 1426).

Roessingh, W./E. Blom, 2011: *Boeren of reizigers langs de limes bij Huissen?*, Amersfoort (ADC-rapport 1569).

Roymans, N., s.a.: *Veehouderij in een late IJzertijd nederzetting aan de Maas te Lith* (Unpublished report).

Roymans, N., 1996: The sword or the plough. Regional dynamics in the romanisation of Belgic Gaul and the Rhineland area, in N. Roymans (ed.), *From the sword to the plough. Three studies on the earliest romanisation of Northern Gaul*, Amsterdam (AAS 1), 9-127.

Roymans, N., 1999: Man, cattle and the supernatural in the Northwest European plain, in C. Fabech/J. Ringtved (eds), *Settlement and landscape. Proceedings of a conference in Århus, Denmark, May 4-7 1998*, Højberg, 291-300.

Roymans, N., 2004: *Ethnic identity and imperial power. The Batavians in the Early Roman Empire*, Amsterdam (AAS 10).

Roymans, N./T. Derks, 1994: *De tempel van Empel. Een Hercules-heiligdom in het woongebied van de Bataven*, ,s-Hertogenbosch (Graven naar het Brabantse Verleden 2).

Scheid, J., 2008: Le statut de la viande *à Rome,* in W. Van Andringa (ed.), *Sacrifices, marché de la viande et pratiques alimentaires dans les cités du monde romain*, Turnhout (Food and History 5 (1)), 19-28.

Schibler, J./A.R. Furger, 1988: *Die Tierknochenfunde aus Augusta Raurica (Grabungen 1955-1974)*, Augst (FiA 9).

Schibler, J./A. Schlumbaum, 2007: Geschichte und wirtschaftliche Bedeutung des Hausrindes (*Bos* *taurus* L.) in der Schweiz von der Jungsteinzeit bis ins frühe Mittelalter, *Schweiz. Arch. Tierheilk.* 149 (1), 23-29.

Schlumbaum, A./B. Stopp/G. Breuer/A. Rehazek/M. Turgay/R. Blatter/J. Schibler, 2003: Combining archaeozoology and molecular genetics: the reason behind the changes in cattle size between 150BC and 700AD in Switzerland, *Antiquity* 77 (298): Project Gallery. http://antiquity.ac.uk/ProjGall/schlumbaum/index.html.

Schmid, E., 1968: Beindrechsler, Hornschnitzer und Leimsieder im römischen Augst, in E. Schmid/L. Berger/P. Bürgin (eds), *Provincialia. Festschrift für Rudolf Laur-Belart*, Basel, 185-197.

Schmid, E., 1972: *Atlas of animal bones. For prehistorians, archaeologists and quaternary geologists*, Amsterdam.

Schrijer, E./F. Reigersman-van Lith de Jeude/W. van Zijverden/K. Esser/K. Hänninen, 2005: *Een archeologische opgraving aan de Molenkampsweg te Brakel*, Amersfoort (ADC-rapport 389).

Schurmans, M., 2005: *Opgraving Houten-Hofstad Diepriool terrein 16*, Amsterdam (ZAR 23).

Schurmans, M., 2007: Sporen en Structuren, in E. Verhelst/M. Schurmans (eds), *Oudheden uit Odijk. Bewoningssporen uit de Late IJzertijd, Romeinse tijd en Merovingische tijd aan de Singel West/Schoudermantel*, Amsterdam (ZAR 30), 23-59.

Schurmans, M., 2008: *Twee nederzettingen op de grens van het Romeinse rijk. Opgraving Huissen Loostraat-Zuid*, Amsterdam (ZAN 139).

Schurmans, M., 2009: *Opgraving Druten-Wilhelminastraat. Romeinse sporen in de periferie van de vindplaats Druten-Klepperhei*, Amsterdam (ZAN 174).

Seetah, K., 2006: Multidisciplinary approach to Romano-British cattle butchery, in M. Maltby (ed.), *Integrating zooarchaeology*, Oxford, 111-118.

Seijnen, M., 1994: Dierebotten en rituele maaltijden, in N. Roymans/T. Derks (eds), *De tempel van Empel. Een Hercules-heiligdom in het woongebied van de Bataven*, ,s-Hertogenbosch (Graven naar het Brabantse Verleden 2), 162-173.

Serjeantson, D., 1989: Animal remains and the tanning trade, in D. Serjeantson/T. Waldron (eds), *Diet and crafts in towns. The evidence of animal remains from the Roman to the Post-Medieval periods*, Oxford (BAR Brit. Ser. 199), 129-146.

Serjeantson, D./J. Morris, 2011: Ravens and crows in Iron Age and Roman Britain, *Oxford Journal of Archaeology* 30 (1), 85-107.

Siemons, H.-A.R., 2001: Sporen en structuren, in M.M. Sier/C.W. Koot (eds), 2001: *Kesteren-De Woerd. Bewoningssporen uit de IJzertijd en de Romeinse tijd*, Amersfoort (RAM 82), 83-112.

Sier, M.M./C.W. Koot (eds), 2001: *Kesteren-De Woerd. Bewoningssporen uit de IJzertijd en de Romeinse tijd*, Amersfoort (RAM 82).

Silver, I.A., 1969 (2nd ed.): The ageing of domestic animals, in D. Brothwell/E. Higgs (eds), *Science in archaeology*, London, 283-302.

Stallibrass, S./R. Thomas, 2008: Food for thought: what's next on the menu?, in S. Stallibrass/ R. Thomas (eds), *Feeding the Roman Army. The Archaeology of Production and Supply in NW Europe,* Oxford, 146-169.

Steenbeek, R., 1990: *On the balance between wet and dry. Vegetation horizon development and prehistoric occupation. A palaeoecological - micromorphological study in the Dutch river area*, Amsterdam (PhD thesis VU University Amsterdam).

Stoffels, E., 2009: Handgevormd aardewerk, in Y. Meijer (ed.), *Gewei uit de geul. LR57: Onderzoek naar een bronstijdrestgeul en sporen uit de vroeg-Romeinse tijd aan de Burgemeester Middelweerdbaan in De Meern, Utrecht*, Utrecht (BRA 31), 131-136.

Stokes, P.R.G., 2000: The butcher, the cook and the archaeologist, in J.P. Huntley/S. Stallibrass (eds), *Taphonomy and interpretation*, Oxford (Symposia of the Association for Environmental Archaeology 14), 65-70.

Stopp, B., 2011: Archäozoologische Auswertung der Grabungen FH 1978/13 und TEW 1978/26 auf dem Basler Münsterhügel, in E. Deschler-Erb, *Der Basler Münsterhügel am Übergang von spätkeltischer zu römischer Zeit. Ein Beispiel für die Romanisierung im Nordosten Galliens, Band A*, Basel (Materialhefte zur Archäologie in Basel 22A), 305-393.

Taayke, E., 1984: *Het beendermateriaal van Houten (-Doornkade) werkputten 25-37*, Groningen (Student's dissertation University of Groningen).

Teichert, M., 1975: Osteometrische Untersuchungen zur Berechnung der Widerristhöhe bei Schafen, in A.T. Clason (ed.), *Archaeozoological Studies*, Amsterdam, 51-69.

Teichert, M., 1984: Size variation in cattle from Germania Romana and Germania Libera, in C. Grigson/J. Clutton-Brock (eds), *Animals in archaeology: 4. Husbandry in Europe*, Oxford (BAR Int. Ser. 227), 93-104.

Therkorn, L.L./E. Besselsen/M. Diepeveen-Jansen/S. Gerritsen/J. Kaarsemaker/M. Kok/L. Kubiak-Martens/J. Slopsma/P. Vos, 2009: *Landscapes in the Broekpolder: excavations around a monument with aspects of the Bronze Age to the Modern (Beverwijk & Heemskerk, Noord-Holland)*, Amsterdam (Themata 2).

Thijssen, J.R.A.M., 1988: *Romeins botmateriaal uit Nijmegen en Woerden*, Amsterdam (Student`s dissertation University of Amsterdam).

Thijssen, J.R.A.M., 1990: Dierebotten, in J.K. Haalebos, *Het grafveld van Nijmegen-Hatert: een begraafplaats uit de eerste drie eeuwen na Chr. op het platteland bij Noviomagus Batavorum*, Nijmegen (Beschrijving van de verzamelingen in het Provinciaal Museum G.M. Kam te Nijmegen 11), 191.

Thijssen, J.R.A.M./C. Vermeeren, 1996: Exotische offers in de Fortunatempel op het Maasplein, in H. van Enckevort/J.R.A.M. Thijssen (eds), *Graven met beleid. Gemeentelijk archeologisch onderzoek in Nijmegen 1989-1995*, Abcoude, 77-80.

Thomas, R., 2005: Zooarchaeology, improvement and the British agricultural revolution, *International Journal of Historical Archaeology* 9 (2), 71-88.

Thomas, R., 2008: Supply-chain networks and the Roman invasion of Britain: a case study from Alchester, Oxfordshire, in S. Stallibrass/R. Thomas (eds), *Feeding the Roman army: the archaeology of production and supply in NW Europe*, Oxford, 31-51.

Thomas, R./S. Stallibrass, 2008: For starters: producing and supplying food to the army in the Roman north-west provinces, in S. Stallibrass/R. Thomas (eds), *Feeding the Roman army: the archaeology of production and supply in NW Europe*, Oxford, 1-17.

Tuinstra, S.J./M.A. Huisman/A. Nieuwhof, 2005: *Een archeologische opgraving in het kader van de aanleg van de infrastructuur in de VINEX-wijk Schuytgraaf te Arnhem-Zuid, gemeente Arnhem (Gld.)*, Groningen (ARC-publicatie 129).

Uerpmann, H.-P., 1977: Schlachterei-Technik und Fleischversorgung im römischen Militärlager von Dangstetten (Landkreis Waldshut), in L. Berger/G. Bienz/J. Ewald/M. Joos (eds), *Festschrift Elisabeth Schmid*, Basel, 261-272.

Valenzuela, A./J.A. Alcover/M.A. Cau, 2013: Tracing changes in animal husbandry in Mallorca (Balearic Islands, Western Mediterranean) from the Iron Age to the Roman period, in M. Groot/D. Lentjes/J. Zeiler (eds), *Barely surviving or more than enough? The environmental archaeology of subsistence, specialisation and surplus food production*, Leiden, 201-223.

Van Andringa, W., 2008: Sacrifices, marché de la viande et pratiques alimentaires dans les cités du monde romain, in W. Van Andringa (ed.), *Sacrifices, marché de la viande et pratiques alimentaires dans les cités du monde romain*, Turnhout (Food and History 5 (1)), 11-15.

Van Beurden, L., 2005: Archeobotanie, in S. Heeren (ed.), *Een nederzetting uit de Romeinse tijd te Tiel-Bedrijvenpark. Medel-Rotonde (vindplaats 6)*, Amsterdam (ZAR 26), 71-76.

Van Beurden, L., 2011: Archeobotanie, in W. Roessingh/E. Blom, 2011: *Boeren of reizigers langs de limes* *bij Huissen?*, Amersfoort (ADC-rapport 1569), 113-118.

Van den Broeke, P., 2002: *Vindplaatsen in vogelvlucht. Beknopt overzicht van het archeologische onderzoek in de Waalsprong (1996-2001)*, Nijmegen (Archeologische Berichten Nijmegen Rapport 1).

Van der Feijst, L.M.B./M.C.M. Langeveld, 2012: Metaal, in E. Blom/L.M.B. van der Feijst/H.A.P. Veldman (eds), 2012: *Plangebied Keizershoeve I. Archeologisch onderzoek op 'De Grote Aalst' te Ewijk*, Amersfoort (ADC-rapport 2000), 195-215.

Van der Feijst, L.M.B./H.A.P. Veldman, 2012: Sporen en structuren, in E. Blom/L.M.B. van der Feijst/H.A.P. Veldman (eds), 2012: *Plangebied Keizershoeve I. Archeologisch onderzoek op 'De Grote Aalst' te Ewijk*, Amersfoort (ADC-rapport 2000), 69-101.

Vanderhoeven, A./A. Ervynck/ W. Van Neer, 1993: De dierlijke en menselijke resten, in A. Vanderhoeven/G. Vynckier/P. Vynckier (eds), Het oudheidkundig bodemonderzoek aan de Veemarkt te Tongeren (prov. Limburg). Eindverslag 1988, *Archeologie in Vlaanderen* 3, 177-186.

Vanderhoeven, A./G. Vynckier/A. Ervynck/W. Van Neer/B. Cooremans, 1994: Het oudheidkundig bodem-onderzoek aan de Minderbroederstraat te Tongeren (prov. Limburg). Eindverslag 1991, *Archeologie in Vlaanderen* 4, 49-74.

Vanderhoeven, A./A. Ervynck, 2007: Not in my back yard? The industry of secondary animal products within the Roman civitas capital of Tongeren, Belgium, in R. Hingley/S. Willis (eds), *Roman finds: context and theory*, Oxford, 156-175.

Van der Jagt, I.M.M./L.M. Kootker/T. van Kolfschoten/H. Kars/G.R. Davies, 2012: An insight into animal exchange in Early Medieval Oegstgeest: a combined archaeozoological and isotopic approach, in D.C.M. Raemaekers/E. Esser/R.C.G.M. Lauwerier/J.T. Zeiler (eds), *A bouquet of archaeozoological studies. Essays in honour of Wietske Prummel*, Groningen, 139-149.

Van der Kamp, J.S., 2007: *Vroege wacht. LR31 Zandweg: archeologisch onderzoek van twee eerste-eeuwse houten wachttorens in Leidsche Rijn*, Utrecht (BRA 16).

Van der Linden, E./K. Huijben/G. Besuijen, 2013: Aardewerk, in R.W. de Groot (ed.), *Een kijkje in het rijksmonument Merm-Wolfhoeksestraat te Elst. Aardgastransportleidingtracé Angerlo-Beuningen (A-663), catalogusnummer 10. Gemeente Overbetuwe. Archaeologisch onderzoek: opgraving*, Weesp (RAAP-rapport 2347), 55-76.

Van der Meer, W., 2008: Archeobotanisch onderzoek, in E. Blom/G.L. Williams (eds), *Archeologisch onderzoek op de locaties Tiel Medel Krommewei en Ooijsche Wetering. Twee archeologische opgravingen*, Amersfoort (ADC-rapport 1010),51-58.

Van der Veen, M./A. Livarda/A. Hill, 2008: New plant foods in Roman Britain – dispersal and social access, *Environmental Archaeology* 13 (1), 11-36.

Van Dijk, J., 2002: Archeozoölogie, in E.E.B. Bulten (ed.), *IJsselstein, Lage Dijk N210*, Amersfoort (ADC-rapport 133), 64-69.

Van Dijk, J., 2008a: Archeozoölogisch onderzoek, in E. Blom/G.L. Williams (eds), *Archeologisch onderzoek op de locaties Tiel Medel Krommewei en Ooijsche Wetering. Twee archeologische opgravingen*, Amersfoort (ADC-rapport 1010), 59-65.

Van Dijk, J., 2008b: Archeozoölogie, in E. Blom/W.K. Vos (eds), Woerden-Hoochwoert. De opgravingen 2002-2004 in het Romeinse castellum Laurium, de vicus en van het schip de 'Woerden 7', Amersfoort (ADC Monografie 2), 301-324.

Van Dijk, J., 2009: Archeozoölogisch onderzoek, in W. Roessingh/E. Blom (eds), *Een omgreppeld nederzettingsterrein uit de Romeinse tijd*, Amersfoort (ADC-rapport 1426), 101-109.

Van Dijk, J., 2010a: *Huisen Loovelden riolering. Archeozoölogisch onderzoek*, Delft (Ossicle 204).

Van Dijk, J., 2010b: Archeozoölogisch onderzoek, in E. Blom/W. Roessingh (eds), *Heteren Uilenburg: 1500 jaar bewoning op een crevasse*, Amersfoort (ADC-rapport 1664), 121-134.

Van Dijk, J., 2010c: Zoöarcheologisch onderzoek, in M.C.M. Langeveld/A. Luksen-IJtsma/E.P.

Graafstal (eds), *Wegens wateroverlast. LR 39 De Balije II: wachttorens, rivierdynamiek en Romeinse infrastructuur in een rivierbocht van de Heldammer Stroom*, Utrecht (BRA 11), 171-176.

Van Dijk, J., 2011a: Archeozoölogie, in W. Roessingh/E. Blom (eds), *Boeren of reizigers langs de limes bij Huissen?*, Amersfoort (ADC-rapport 1569), 103-112.

Van Dijk, J., 2011b: Archeozoölogie, in H.A.P. Veldman (ed.), *Graven in Zoelen. De opgraving van een Romeinse nederzetting en grafveld*, Amersfoort (ADC-rapport 2391), 177-190.

Van Dijk, J., 2012: Archeozoölogie, in E. Blom/L.M.B. van der Feijst/H.A.P. Veldman (eds), 2012: *Plangebied Keizershoeve I. Archeologisch onderzoek op 'De Grote Aalst' te Ewijk*, Amersfoort (ADC-rapport 2000), 231-250.

Van Dijk, J./M. Groot, 2013: The Late Iron Age-Roman transformation from subsistence to surplus production in animal husbandry in the Central and Western parts of the Netherlands, in M. Groot/D. Lentjes/J. Zeiler (eds), *Barely surviving or more than enough? The environmental archaeology of subsistence, specialisation and surplus food production,* Leiden, 175-200.

Van Dinter, M./L.I. Kooistra/M.K. Dütting/P. van Rijn/C. Cavallo, 2014: Could the local population of the Lower Rhine delta supply the Roman army? Part 2: Modelling the carrying capacity using archaeological, palaeo-ecological and geomorphological data, *Journal of Archaeology in the Low Countries* 5 (1), 5-50.

Van Driel-Murray, C., 1985: The production and supply of military leatherwork in the first and second centuries A.D.: a review of the archaeological evidence, in M.C. Bishop (ed.), *The production and distribution of Roman military equipment. Proceedings of the Second Roman Military Equipment Research Seminar*, Oxford (BAR Int. Ser. 275), 43-81.

Van Driel-Murray, C., 2000: Technology transfer: the introduction and loss of tanning technology during the Roman period, in M. Polfer (ed.), *L'artisanat romain: évolutions, continuités et ruptures (Italie et provinces occidentales)*, Montagnac, 55-67.

Van Driel-Murray, C., 2003: Ethnic soldiers: the experience of the Lower Rhine tribes, in T. Grünewald/S. Seibel (eds), *Kontinuität und Diskontinuität. Germania Inferior am Beginn und am Ende der römischen Herrschaft*, Berlin/New York, 200-217.

Van Driel-Murray, C., 2008: Leer, in M. Schurmans (ed.), 2008: *Twee nederzettingen op de grens van het Romeinse rijk. Opgraving Huissen Loostraat-Zuid*, Amsterdam (ZAN 139), 102.

Van Driel-Murray, C., 2011: Are we missing something? The elusive tanneries of the Roman period, in R. Thomson/Q. Mould (eds), *Leather tanneries: the archaeological evidence*, London, 69-83.

Van Enckevort, H./J. Thijssen, 1996: *Graven met beleid. Gemeentelijk archeologisch onderzoek in Nijmegen 1989-1995*, Abcoude.

Van Enckevort, H./K. Zee, 1996: *Het Kops Plateau. Prehistorische grafheuvels en een Romeinse legerplaats in Nijmegen*, Abcoude/Amersfoort.

Van Enckevort, H./J. Thijssen, 2005: *In de schaduw van het noorderlicht. De Gallo-Romeinse tempel van Elst-Westeraam*, Abcoude (Archeologische Berichten Nijmegen 6).

Van Es, W.A., 1981 (2nd ed.): *De Romeinen in Nederland*, Haarlem.

Van Haaster, H., 2002: Botanisch onderzoek, in E.E.B. Bulten (ed.), *IJsselstein, Lage Dijk N210*, Amersfoort (ADC-rapport 133), 17-24.

Van Haaster, H., 2005: Verbrand graan en onkruiden, in H. van Enckevort/J. Thijssen (ed.), *In de schaduw van het Noorderlicht. Een Gallo-Romeinse tempel te Elst-Westeraam*, Abcoude, 87-89.

Van Haaster, H., 2007: Pollen- en macrorestenonderzoek: voedselgewassen en vegetatie-reconstructie, in J.S. van der Kamp (ed.), *Vroege wacht. LR31 Zandweg: archeologisch onderzoek van twee eerste-eeuwse houten wachttorens in Leidsche Rijn*, Utrecht (BRA 16), 158-164.

Van Haaster, H., 2009: Archeobotanie, in A. Luksen-Ijtsma (ed.), *Oudenrijnseweg. Archeologisch onderzoek van een inheems-Romeinse nederzetting uit de eerste eeuw na Chr. en een vlasrootcomplex uit de twaalfde* *eeuw na Chr in De Meern, gemeente Utrecht*, Utrecht (BRA 25), 63-70.

Van Haaster, H., 2010: Botanisch onderzoek, in H.A.P. Veldman/E. Blom (eds), *Onder de zoden van Zaltbommel,* Amersfoort (ADC Monografie 8), 249-264.

Van Haaster, H., 2013: Archaeobotanisch onderzoek, in L. Dielemans (ed.), *Wacht aan het water. VLEN3-00: archeologisch onderzoek naar sporen en vondstassemblages uit de Romeinse tijd in Vleuterweide*, Utrecht (BRA 52), 147-157.

Van Haaster, H./P. van Rijn, 2002: Archeobotanisch onderzoek, in E.M.P. Verhelst (ed.), *Aanvullend archeologisch onderzoek in het tracé van de Betuweroute, vindplaats 52 Geldermalsen/Rijs en Ooyen*, Amersfoort (RAM 43), 67-70.

Van Kerckhove, J., 2008: Aardewerk, in M. Schurmans (ed.), *Twee nederzettingen op de grens van het Romeinse rijk. Opgraving Huissen Loostraat-Zuid*, Amsterdam (ZAN 139), 37-71.

Van Kerckhove, J., 2009: Aardewerk, in J. van Renswoude/J. Van Kerckhove (eds), *Opgravingen in Geldermalsen-Hondsgemet. Een inheemse nederzetting uit de Late IJzertijd en Romeinse tijd*, Amsterdam (ZAR 35), 115-192.

Van Londen, H., 2006: *Midden-Delfland: the Roman native landscape. Past and present*, Amsterdam (PhD thesis University of Amsterdam).

Van Mensch, P.J.A., 1974: *Archeozoölogisch onderzoek van de dierresten uit het castellum te Zwammerdam*, Amsterdam (Internal report University of Amsterdam).

Van Mensch, P.J.A., 1979: A Roman soup-kitchen at Zwammerdam?, *BROB* 24, 159-165.

Van Mensch, P.J.A./G.F. IJzereef, 1977: Smoke-dried meat in prehistoric and Roman Netherlands, in B.L. van Beek/R.W. Brandt/W. Groenman-van Waateringe (eds), *Ex Horreo: IPP 1951-1976*, Amsterdam, 144-150.

Van Renswoude, J., 2008a: Metaal, in M. Schurmans (ed.), *Twee nederzettingen op de grens van het Romeinse rijk. Opgraving Huissen Loostraat-Zuid*, Amsterdam (ZAN 139), 74-84.

Van Renswoude, J., 2008b: Metaal, in T. Derks/J. Van Kerckhove/P. Hoff (eds), *Nieuw archeologisch onderzoek rond de Grote Kerk van Elst, gemeente Overbetuwe (2002-2003)*, Amsterdam (ZAR 31), 74-82.

Van Renswoude, J., 2009a: Sporen en structuren, in J. van Renswoude/J. Van Kerckhove (eds), *Opgravingen in Geldermalsen-Hondsgemet. Een inheemse nederzetting uit de Late IJzertijd en Romeinse tijd*, Amsterdam (ZAR 35), 85-114.

Van Renswoude, J., 2009b: Synthese, in J. van Renswoude/J. Van Kerckhove (eds), *Opgravingen in Geldermalsen-Hondsgemet. Een inheemse nederzetting uit de Late IJzertijd en Romeinse tijd*, Amsterdam (ZAR 35), 459-475.

Van Renswoude, J., 2009c: Metaal, in J. van Renswoude/J. Van Kerckhove (eds), *Opgravingen in Geldermalsen-Hondsgemet. Een inheemse nederzetting uit de Late IJzertijd en Romeinse tijd*, Amsterdam (ZAR 35), 231-286.

Van Renswoude, J./J. Van Kerckhove, 2009: *Opgravingen in Geldermalsen-Hondsgemet. Een inheemse nederzetting uit de Late IJzertijd en Romeinse tijd*, Amsterdam (ZAR 35).

Van Rijn, P., 2013: Fuiken, in L. Dielemans (ed.), *Wacht aan het water. VLEN3-00: archeologisch onderzoek naar sporen en vondstassemblages uit de Romeinse tijd in Vleuterweide*, Utrecht (BRA 52), 135-145.

Veldman, H.A.P., 2010: Sporen en structuren, in H.A.P. Veldman/E. Blom (eds), *Onder de zoden van Zaltbommel,* Amersfoort (ADC Monografie 8), 41-99.

Veldman, H.A.P., 2011: *Graven in Zoelen. De opgraving van een Romeinse nederzetting en grafveld*, Amersfoort (ADC-rapport 2391).

Veldman, H.A.P./E. Blom, 2010: *Onder de zoden van Zaltbommel,* Amersfoort (ADC Monografie 8).

Verhelst, E.M.P., 2001: *Passewaaij Oude Tielseweg. Chronologie, structuur en materiële cultuur van een inheemse nederzetting in het Bataafse stamgebied*, Amsterdam (Master's dissertation University of Amsterdam).

Verhelst, E.M.P., 2002: *Aanvullend archeologisch onderzoek in het tracé van de Betuweroute, vindplaats 52*

Geldermalsen/Rijs en Ooyen, Amersfoort (RAM 43).
Verhelst, E., 2006: Metaal, in S. Heeren, *Opgravingen bij Tiel-Passewaaij 1. De nederzetting aan de Passewaaijse Hogeweg*, Amsterdam (ZAR 29), 145-153.
Verhelst, E., 2007: Metaal, in E. Verhelst/M. Schurmans (eds), *Oudheden uit Odijk. Bewoningssporen uit de Late IJzertijd, Romeinse tijd en Merovingische tijd aan de Singel West/Schoudermantel*, Amsterdam (ZAR 30), 93-124.
Verhelst, E./M. Schurmans, 2007: *Oudheden uit Odijk. Bewoningssporen uit de Late IJzertijd, Romeinse tijd en Merovingische tijd aan de Singel West/Schoudermantel*, Amsterdam (ZAR 30).
Verhelst, E.M.P., 2012: *Plangebied Ingen-Het Woud, Gemeente Buren. Archeologisch vooronderzoek: een inventariserend veldonderzoek (proefsleuven)*, Weesp (RAAP-rapport 2513).
Verhelst, E.M.P., 2013: Metaal, in R.W. de Groot (ed.), *Een kijkje in het rijksmonument Merm-Wolfhoeksestraat te Elst. Aardgastransportleidingtracé Angerlo-Beuningen (A-663), catalogusnummer 10. Gemeente Overbetuwe. Archaeologisch onderzoek: opgraving*, Weesp (RAAP-rapport 2347), 101-113.
Vigne, J.-D./D. Helmer, 2007: Was milk a "secondary product" in the Old World Neolithisation process? Its role in the domestication of cattle, sheep and goats, *Anthropozoologica* 42 (2), 9-40.
Viner, S./J. Evans/U. Albarella/M. Parker Pearson, 2010: Cattle mobility in prehistoric Britain: strontium isotope analysis of cattle teeth from Durrington Walls (Wiltshire, Britain), *JAS* 37, 2812-2820.
Von den Driesch, A./J. Boessneck, 1974: Kritische Anmerkungen zur Widerristhöhenberechnung aus Längenmassen vor- und frühgeschichtlicher Tierknochen, *Säugetierkundliche Mitteilungen* 22, 325-348.
Von den Driesch, A., 1976: *Das Vermessen von Tierknochen aus vor- und frühgeschichtlichen Siedlungen*, München.
Vos, W.K., 2000: *Archeologisch onderzoek Houten-Zuid op terrein 8A*, Amersfoort (ADC-rapport 30).
Vos, W.K., 2009: *Bataafs platteland. Het Romeinse nederzettingslandschap in het Nederlandse Kromme-Rijngebied*, Amersfoort (NAR 35).
Vossen, I., 2003: The possibilities and limitations of demographic calculations in the Batavian area, in T. Grünewald/ S. Seibel (eds), *Kontinuität und Diskontinuität. Germania inferior am Beginn und am Ende der römischen Herrschaft*, Berlin/New York, 414-435.
Vossen, I./M. Groot, 2009: *Barley and Horses: Surplus and Demand in the* civitas Batavorum, in M. Driessen/S. Heeren/J. Hendriks/F. Kemmers/R. Visser (eds), *TRAC 2008. Proceedings of the 18th annual Theoretical Roman Archaeology Conference held at Amsterdam 4-6 April, 2008,* Oxford, 89-104.
Weinstock, J., 2000: Osteometry as a source of refined demographic information: sex-ratios of reindeer, hunting strategies, and herd control in the Late Glacial site of Stellmoor, Northern Germany, *JAS* 27, 1187-1195.
Wells, P., 1996: Production within and beyond imperial boundaries: goods, exchange and power in Roman Europe, *Journal of World-Systems Research* 2 (1).
Weterings, P., 2010: Bewoningsactiviteit aan een restgeul, in M.C.M. Langeveld/A. Luksen-IJtsma/P. Weterings (eds), *Een goede buur? LR46 en LR49: definitief archeologisch onderzoek naar de vicus, grafvelden, infrastructuur en een inheemse nederzetting in de omgeving van het Romeinse castellum in De Meern, deelgebied 'De Woerd' (Gemeente Utrecht)*, Utrecht (BRA 19), 29-55.
Weterings, P.G.H./Y. Meijer, 2011: *Op zoek naar de weg. LR60: onderzoek naar de Romeinse limesweg in De Meern (gemeente Utrecht)*, Utrecht (BRA 33).
White, K.D., 1970: *Roman farming*, London.
Whittaker, W.E., 2002: *Zooarchaeological analysis of the Roman frontier economy in the Eastern Netherlands*, Iowa City, Iowa (PhD thesis University of Iowa).
Willems, W.J.H., 1984: Romans and Batavians: a regional study in the Dutch eastern river area II, *BROB* 34, 39-331.

Willems, W.J.H., 1990: *Romeins Nijmegen. Vier eeuwen stad en centrum aan de Waal*, Utrecht.

Willems, W.J.H./H. van Enckevort (eds), 2009: *Ulpia Noviomagus. Roman Nijmegen: the Batavian capital at the imperial frontier*, Portsmouth, Rhode Island (JRA Supplementary Series 73).

Wilson, B., 1994: Mortality patterns, animal husbandry and marketing in and around medieval and post-medieval Oxford, in A.R. Hall/H.K. Kenward (eds.), *Urban-rural connexions: perspectives from environmental archaeology*, Oxford, 103-115.

Zawatka, D./H. Reichstein, 1977: Untersuchungen an Tierknochenfunden von den römerzeitlichen Siedlungsplätzen Bentumersiel und Jemgumkloster an der unteren Ems/Ostfriesland, *Probleme der Küstenforschung im südlichen Nordseegebiet* 12, 85-128.

Zeder, M.A., 1991: *Feeding Cities: Specialized Animal Economy in the Ancient Near East*, Washington (Smithsonian Series in Archaeological Inquiry).

Zeiler, J.T., 1997: Offers en slachtoffers. Faunaresten uit de Fortunatempel te Nijmegen (2e eeuw n. Chr.), *Paleoaktueel* 8, 105-107.

Zeiler, J.T., 2001: Archeozoölogie, in M.M. Sier/C.W. Koot (eds), 2001: *Kesteren-De Woerd. Bewoningssporen uit de IJzertijd en de Romeinse tijd*, Amersfoort (RAM 82), 217-291.

Zeiler, J.T., 2005: Paardenrookvlees uit Kesteren (Gld.), *Paleoaktueel* 14/15, 143-145.

Zeiler, J.T., 2006: *Dierlijke resten uit Ockenburgh. Archeozoölogisch onderzoek van botmateriaal uit Ockenburgh, gem. Den Haag, (IJzertijd en Romeinse tijd)*, Leeuwarden (ArchaeoBone rapport).

Zeiler, J.T., 2007: Archeozoölogie, in E. Verhelst/M. Schurmans (eds), *Oudheden uit Odijk. Bewoningssporen uit de Late IJzertijd, Romeinse tijd en Merovingische tijd aan de Singel West/Schoudermantel*, Amsterdam (ZAR 30), 159-180.

Zeiler, J.T./J. van Dijk/L.M. Kootker/D.C. Brinkhuizen, 2010: *Een haven vol botten. Archeozoölogisch onderzoek van botmateriaal uit de Romeinse haven Velsen 2, (ca. 30-50 n.Chr.)*, Haren (ArchaeoBone rapport 84).

Zuidhoff, F.S./J.A.A. Bos/M.T.I.J. Bouman/C. Moolhuizen, 2011: Landschap en vegetatie rond Zoelen Scharenburg, in H.A.P. Veldman (ed.), *Graven in Zoelen. De opgraving van een Romeinse nederzetting en grafveld*, Amersfoort (ADC-rapport 2391), 21-50.

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